United States
Environmental Protection
Agency
Air

May 11,
1993
EPA-AA-AQAB-93-01
NTIS PB94-129905

EPA

Evaluation of a Four-Mode Steady-State Test With Acceleration Simulation Modes As An Alternative Inspection and Maintenance Test for Enhanced I/M Programs

William M. Pidgeon
Daniel J. Sampson
Paul H. Burbage IV
Larry C. Landman
William B. Clemmens
Erik Herzog
David J. Brzezinski
David Sosnowski

1. Executive Summary

1.1 Purpose

On November 5, 1992, the U.S. Environmental Protection Agency (EPA) promulgated a regulation[1] for state-operated enhanced Inspection and Maintenance (I/M) programs. This regulation established the IM240 [2] as the benchmark I/M test, against which any alternative test must be found equivalent, or nearly so but with compensating improvements in other program aspects.

EPA performed tests on over 1500 vehicles in Mesa, Arizona to evaluate a four-mode, steady-state procedure utilizing two Acceleration Simulation Modes [3]. (This four-mode test procedure will herein be referred to as the “ASM” test, although only the first two modes are strictly ASM modes.) This evaluation was designed for determining whether the ASM is a suitable alternative to the IM240 for enhanced I/M testing.

The ASM test utilizes equipment costing about half of the anticipated cost of the equipment required for IM240 testing. This equipment is less expensive because the ASM does not involve transient driving and the equipment only approximates mass emissions via pollutant concentration measurements. In contrast, the IM240 is a transient test requiring more expensive equipment measuring true mass emissions during typical driving.

The purpose of this document is to provide:

- EPA’s evaluation regarding the effectiveness of the ASM test;
- a description of the analysis techniques EPA used;
- the data used in the evaluation; and
- a description of the test program.

This is the only ASM study conducted in an official I/M station. The vehicles were randomly selected and tested under the widely varying ambient conditions and preconditioning

---

[1] Inspection/Maintenance Program Requirements; Final Rule 40 CFR Part 51, Federal Register, November 5,1992

[2] William M. Pidgeon, and Natalie Dobie, “The IM240 Transient I/M Dynamometer Driving Schedule and The Composite I/M Test Procedure,” EPA-AA-TSS-91-1, January 1991

[3] Thomas C. Austin and Larry Sherwood, “Development of Improved Loaded-Mode Test Procedures for Inspection and Maintenance Programs,” Sierra Research, Inc. and California Bureau of Automotive Repair, SAE Technical Paper No. 891120, May 1989.

that normally attend official I/M tests. Many more cars were tested than in any other ASM study. Also, this is the only study to use one sample to develop the ASM mode weighting factors and an independent sample to evaluate their effectiveness. EPA strongly believes that this study should be given far more weight than all previous ASM studies.

1.2 Findings

EPA's findings are based on performance comparisons between the ASM and the IM240 regarding five important considerations:

- their relative ability to fail malfunctioning vehicles (needing exhaust emission control system repairs) and to avoid failing properly functioning vehicles;

- their relative ability to distinguish repaired vehicles (exhaust-repairs) that are sufficiently repaired from those that are insufficiently repaired;

- their relative ability to distinguish between functioning and malfunctioning evaporative canister purge systems;

- their relative costs; and

- the adequacy of the ASM for Enhanced I/M Programs using MOBILE5a.

1.2.1 Ability to Correctly Identify Vehicles Needing Repair

EPA commonly uses the rate of excess emissions identified during an I/M test to objectively and quantitatively compare I/M test procedures. Excess emissions are those FTP-measured emissions that exceed the certification emission standards for the vehicle under consideration. For example, a vehicle certified to the 0.41 g/mi HC standard whose FTP result was 2.00 g/mi, would have excess emissions equalling 1.59 g/mi HC (i.e., 2.00 - 0.41 = 1.59).

The excess emissions identification rate (IDR) equals the sum of the excess emissions for the vehicles failing the I/M test divided by the total excess emissions. The more excess emissions an I/M test identifies, the better the test.

EPA uses IDR instead of merely comparing the number of vehicles that correctly fail and correctly pass. The IDR better contrasts the relative merits of competing I/M test procedures because failing vehicles with high emissions is more important than failing those that are only slightly above their certification standards. For example, take two I/M procedures that correctly failed 100 of the 500 vehicles that had FTP emissions greater than their certification standards, but only 50 cars failed both tests. If the fifty cars that failed Test A were high FTP emitters, and the other 50 cars that failed Test B had FTP emissions only slightly above their standards, obviously Test A would be preferred, and its IDR would reflect its better performance. Test A's better performance is not evident in comparing the number of vehicles that correctly fail.

The ASM does not find high emitting vehicles as well as the IM240. Some high emitters which could be caught with the IM240 give low ASM scores. Table 1.2.1 shows the percent decrease in the excess emissions identification rate that would accompany substituting the ASM for the IM240. For example, an IM240-based I/M program's HC and NOx IDRs will suffer nearly a 20% decrease by substituting the ASM test at the same failure rate (18%) that is produced by EPA's recommended cutpoints for biennial I/M programs.

Table 1.2.1 Loss in Identification Effectiveness With ASM Test

Scenario	HC	CO	NOx
Failure Rate Held at 18% (0.8/15/2.0 + 0.50/12.0 IM240 Cutpoints)	19.0%	9.5%	18.5%
Best IDRs with Ecs Held Below 5%	14.0%	14.3%	17.5%

These values are % differences. For example: $\frac{(92.2-74.7)}{92.2}$ * 100 = 19.0%

Source: Table 5.3.1, Section 5.3

An aggressive I/M program, tolerating both higher failure rates and higher false-failure rates would relinquish about 15% of its inspection effectiveness by substituting the ASM test.

Additional related findings are listed below:

- The ASM fails cars that are actually clean more often than the IM240. About 1 in 10 cars failed by the ASM did not appear to need repair, compared to about 1 in 30 for the IM240. EPA knows from other testing that more preconditioning can eliminate IM240 errors; we are not sure whether it can for ASM failures.

- Making ASM cutpoints more stringent in an attempt to get the same effectiveness as the IM240 increases the failure rate and/or the error rate beyond what EPA believes any I/M program would want or is willing to commit to in binding regulation form.

The comparative ability to identify vehicles needing repair is fully discussed in Section 5.3. Why IDRs and associated criteria are important, how the criteria are derived, and the tradeoffs associated with increasing cutpoint stringency to increase IDRs are discussed in Section 5.2.

1.2.2 Ability to Distinguish Sufficiently Repaired Vehicles From Insufficiently Repaired Vehicles

Vehicles that do fail the ASM test and get repaired, can pass ASM cutpoints with repairs that are not as effective as the repairs needed to pass IM240 cutpoints, even when repaired in good faith. Also, the ASM modes are prone to "adjust to pass/readjust after" strategies like the idle and 2500/idle tests.

Several of the 17 cars which failed the Arizona test and the ASM were repaired in local shops, after which they passed the Arizona and ASM test but still had high IM240 emissions. This is the same pattern seen in 2500/idle I/M programs. Repair analyses are discussed in Section 5.6.

1.2.3 Ability to Distinguish Between Functioning and Malfunctioning Evaporative Canister Purge Systems

In purge testing, the ASM and the IM240 should do equally well in identifying malfunctioning purge systems, so their comparative ability to fail vehicles with malfunctioning purge systems has not been an issue. Therefore, the research issue has been whether, and how many properly functioning vehicles would fail. That is, EPA is more concerned with errors-of-commission than with errors-of-omission. About 4-6% of the vehicles failed the ASM evaporative canister purge system test but were actually properly functioning. This is about 38% to 52% of all cars that failed the ASM purge.
About 1% of the vehicles failed the IM240 purge system test, but were actually properly functioning. This is about 12% to 18% of all cars that failed the IM240 purge.

Unlike transient IM240 testing, which requires vehicles to operate through a wide range of speeds and loads, the four steady-state modes of the ASM do not provide a purge opportunity for a significant portion of the fleet. The purge system test results are discussed in Section 5.7.

1.2.4 Test Costs

The 180 seconds required for this four-mode ASM test is the same as would be needed for the IM240 if special algorithms are used to pass obviously clean cars and fail obviously dirty cars early in the cycle. So, the ASM does not save test time or reduce the number of lanes required. A shorter test based on fewer than four modes would have even less benefit.

The only cost advantage for this ASM test is that up to about half the equipment cost can be avoided by not having variable inertia capability in the dynamometer and low-concentration measurement capability in the gas analysis instruments. This savings works out to about 75 cents per test in a centralized program. Test costs are discussed in Section 7.

1.2.5 Adequacy of the ASM for Enhanced I/M Programs

The MOBILE5a analysis results show that even in a maximum annual program, covering all weight classes, with ASM, purge, and pressure testing of all model years and comprehensive anti-tampering inspections, the ASM test yields insufficient benefits to meet the performance standard for HC, CO, or NOx.

2. Background

EPA began development of a transient I/M test procedure, named the IM240, during 1989. EPA published a Notice of Proposed Rulemaking on July 13, 1992 which proposed a performance standard for enhanced I/M programs that assumed the use of the IM240 test procedure.

On May 8, 1992, ARCO Products Company released a report [4] recommending that an alternative to the IM240 be allowed for enhanced I/M programs. The operating modes for ARCO's alternative procedure were not conclusively determined, but the modes were based on "Acceleration Simulation Mode" procedures developed by the California Bureau of Automotive Repair and Sierra Research, Inc.

In contrast to ARCO's report which was somewhat ambiguous on which modes should be included in the alternative test, the earlier BAR/Sierra report [5] had recommended an ASM I/M test that included the traditional 2500/idle test (2 modes) with two loaded dynamometer modes, at 15 mph and at 25 mph. The authors concluded that these two dynamometer modes were needed for NOx correlation with the FTP [*], and that the 2500/idle modes were necessary for good HC/CO correlation.

ARCO's report, which reached different conclusions, was based on test results from five newer vehicles that were tested with and without implanted malfunctions, resulting in 30 tests. ARCO's conclusions are directly quoted below:

1. An enhanced IM program utilizing steady-state exhaust emission testing is as effective in identifying cars needing repair as is the EPA's proposed IM240 test. Because the cost of the IM240 equipment is four times that of an enhanced I/M test, the enhanced I/M test is far more cost effective.

2. Canister purging can be tested as effectively in an enhanced I/M test as in an IM240 test.

3. The current BAR90 exhaust emissions test conditions of idle and 2500 rpm/no load are not effective in identifying most malfunctions in state-of-the-art automobiles.

---

[4] Kenneth L. Boekhaus, Brian K. Sullivan, and Charles E. Gang, "Evaluation of Enhanced Inspection Techniques on State-of-the-Art Automobiles," ARCO Products Company, May 8, 1992.

[5] Austin and Sherwood.

[*] The Federal Test Procedure (FTP) is a mass emissions test created to determine whether prototype vehicles comply with EPA standards, thus allowing production vehicles to be certified for sale in the United States. The FTP has become the "gold standard" for determining vehicle emission levels, so it is also used to determine the emission levels of "in-use" vehicles. The FTP is too costly to use for I/M because vehicles must be maintained in a closely controlled environment for over 13 hours. The FTP driving cycle includes 31 minutes of actual driving which takes 41 minutes to complete due to a 10 minute engine shut-off between the second and third modes of this 3 mode test.

4. The ASM5015 steady-state test condition is effective in identifying malfunctions for HC, CO and NOx and should be included in any enhanced I/M test developed.

5. Further development work is needed to develop one or more other steady-state test conditions to complement the ASM5015 test.

6. The IM240 test correlates better with the FTP test in predicting absolute emissions levels than does the ASM5015 test. With one or more additional steady-state test conditions, steady-state testing would likely correlate as well as the IM240 test.

7. The BAR 90 Test Analyzer System, with NOx analyzer, can be used for enhanced I/M testing incorporating a steady-state dynamometer.[6]

On November 5, 1992, EPA promulgated the final I/M rule establishing the IM240 as the benchmark I/M test, against which any alternative test must be found equivalent. The IM240 is a transient test which measures true mass emissions during typical driving. In contrast, the Acceleration Simulation Mode procedures only approximate mass emissions via pollutant concentration measurements during several steady-state modes. A BAR90 HC and CO analyzer with an NO analyzer is sufficient. Emissions measurements are not made during the accelerations and decelerations between the steady-state driving modes because such measurements require more expensive equipment including a constant volume sampler to dilute the exhaust and measure flow, and analyzers capable of accurately measuring the resulting low concentration samples.

The purpose of EPA's alternative I/M test procedure study is to evaluate whether the IM240's performance as an I/M test can be attained, or nearly so, by a multi-mode, steady-state procedure (including two ASM modes) that utilizes equipment costing about half of the anticipated cost of the equipment required for IM240 testing.

Due to widespread interest and the need for states to move forward with specific testing plans, EPA prepared to initiate a test program to evaluate a steady-state loaded I/M test as a potential alternative to the IM240 for enhanced I/M. EPA's alternative test study focused on the Acceleration Simulation Mode procedures.

EPA needed to select a practicable number of steady-state operating modes, but there was disagreement among the proponents of steady-state testing for enhanced I/M. ARCO concluded that the 2500 rpm & idle modes are not effective for identifying most malfunctions. In contrast, BAR/Sierra recommended an I/M test consisting of the following modes: 5015, 2525, 2500 rpm, and idle.

EPA's desire to evaluate a single steady-state procedure agreeable to all interested parties led to a conference call with the interested parties on July 27, 1992. The

[6] Boekhaus, et al.

participants included: ARCO, Sierra Research, California Bureau of Automotive Repair, Allen Test Products/SAVER, EPA's Testing Contractor (Automotive Testing Labs), and EPA.

The parties reached a consensus that the steady-state test to be evaluated should include four modes (a fifth mode was only to be performed on the first 50 cars with automatic transmissions):

- 15 mph (ASM 5015) *
- 25 mph (ASM 2525) **
- 50 mph at road load horsepower ***
- idle (automatic transmissions using Drive rather than Neutral) ****
- idle (first 50 vehicles with automatic transmissions using Neutral rather than Drive) ****

This test procedure will herein be referred to as the "ASM" procedure, although only the first two modes are strictly ASM modes.

---

* This is a steady-state 15 mph mode (50 **15**). The dynamometer load is set to simulate 50% (**50**15) of the power required to accelerate the particular vehicle being tested at 3.3 mph/second at 15 mph. The ASM does not include a true speed changing acceleration during emissions measurement, instead the speed is held constant while the dynamometer load is set to simulate the power required to accelerate the car. The 3.3 mph/second acceleration rate is the maximum acceleration rate during the Federal Test Procedure (FTP). The FTP is the transient (accelerations and decelerations) procedure used to certify that vehicles comply with Federal emissions standards, which is required before the manufacturer can offer them for sale. The IM240, for the most part, is taken directly from the FTP. The 5015 mode usually requires a higher load setting than the 2525 or the 50 mph road load modes.

** This is a steady-state 25 mph mode (25 **25**). It is analogous to the ASM5015 mode in that the dynamometer load set to simulate 25% (**25**25) of the power required to accelerate the particular vehicle being tested at 3.3 mph/second at 25 mph.

*** This is a 50 mph mode with the dynamometer set to the power required for a vehicle to maintain 50 mph on level road taking into account air resistance, tire losses, bearing friction in the drivetrain, etc. Air drag is the major resistance at 50 mph.

**** Because the vehicles were to be operated on the dynamometer, it was judged that the vehicles could be safely tested at idle in Drive. Because automatic-transmission-equipped vehicles idle in drive during the FTP, and some ECM algorithms for the emission control system change with transmission selector position, idle in Drive is expected to yield better correlation with the FTP than idle in Neutral. Since all known idle emissions tests had been run in Neutral prior to EPA's ASM evaluation, the first 50 vehicles, or more, were also run in Neutral to allow comparison with other databases.

Having reached a consensus on the procedure to be evaluated, EPA issued a work assignment [7] on July 30, 1992, directing EPA's testing contractor to implement the new procedure. Shakedown testing began in August and the first official ASM test was performed on September 10, 1992. The last as-received ASM test was performed at the I/M lane on March 19, 1993. This analysis includes tests that were performed through February 17, 1993.

Another issue EPA must consider is the impact of approving alternative I/M procedures on the automobile manufacturers. The Motor Vehicle Manufacturers Association, in written comments on the I/M NPRM, said:

> 6.0.0 ALTERNATIVE TEST METHODS
>
> MVMA agrees that EPA should not allow enhanced I/M areas to implement alternative tests until they have submitted substantial data supporting the quality of the test, and showing that the test produces emission reductions equivalent to those of the IM240 Test.
>
> One such report by ARCO describes an acceleration simulation mode (ASM) that was compared to the IM240 test. A substantial cost advantage with this alternative test is that it does not require the use of a constant volume sample (CVS) sampling system. The report references an earlier study by Sierra Research that calculates mass emissions by multiplying a "constant" times "emissions concentration" times "inertia weight". Yet during the comparison of the two test methods, the mass emissions for the ASM were measured utilizing a CVS. For a more accurate comparison, the ASM data should have been calculated in the method prescribed for use in the field, i.e., with BAR-90 readings and without the use of CVS equipment.
>
> Probably of greater concern, however, is the cutpoints selected for each test process. Since cutpoints are an important criteria in comparing and evaluating test processes, realistic cutpoints have to be determined before an accurate comparison can be made. The IM240 Test cutpoints selected for this [ARCO's] comparison are extremely low and thus "create" false failures. In contrast, the [ARCO] selection process for the ASM cutpoints is not well explained and remains ambiguous, making IM240 Test versus ASM Test comparison speculative at best.
>
> ARCO used only five vehicles in the study. Their objective was to "evaluate the viability of an alternative enhanced I/M test." It appears much more work is required before such an alternative could be properly defined and evaluated. In the NPRM preamble, EPA stated that if this ASM test can be shown to be as effective as the IM240 Test, it could be permitted as a "substitute". MVMA is concerned that "substitute" tests could lead to several alternative tests with varying degrees of effectiveness. MVMA requests that EPA continue to critically assess any alternative tests proposed by enhanced I/M areas. This review process will help assure that any alternative tests are able to properly identify failing vehicles.

EPA is also puzzled by ARCO's conclusions which seem contradictory. ARCO's first conclusion states:

---

[7] Statement of Work Change 1, July 30, 1992; Work Assignment 0-2, Contract No. 68-CI-0055, "Test Procedure to Evaluate the Acceleration Simulation Mode and the Emissions Measurement Capabilities of a BAR90 Certified Analyzer With An Integrated Fuel Cell Type NO Analyzer."

> An enhanced IM program utilizing steady-state exhaust emission testing is as effective in identifying cars needing repair as is the EPA's proposed IM240 test.

Their fourth conclusion states that:

> The ASM5015 steady-state test condition is effective in identifying malfunctions for HC, CO and NOx and should be included in any enhanced I/M test developed.

ARCO's fifth conclusion states that:

> Further development work is needed to develop one or more other steady-state test conditions to complement the ASM5015 test.

These statements suggest that ARCO's testing indicated that the ASM5015 was not as effective as the IM240, that the other modes they evaluated were not helpful, and additional work was required to identify better alternatives. This report will document additional work performed by EPA to evaluate the ASM5015 and three additional steady-state modes.

3. Test Procedures

The best way to compare I/M tests is to utilize actual results from an I/M station in conjunction with FTPs run on a subset of the vehicles also tested at the I/M station. A highly inferior method is to compare the procedures based only on test data collected in a laboratory which is not subject to the range of vehicle operating conditions which normally precede actual I/M tests, nor the range of ambient conditions encountered during actual I/M tests.

It is widely acknowledged that a given vehicle's emissions can vary widely with changes in vehicle operating conditions that precede emissions tests, and a given vehicle's emissions can vary widely with ambient conditions encountered during an emissions test. So, in contrast to laboratory test results, the results from pilot tests run in an official I/M station provide significantly more confidence that the pilot test results will accurately represent future results when the procedure is mandated for official I/M testing.

For these reasons, EPA carried out IM240 and ASM testing (through a contractor) in an I/M station in Mesa, Arizona, with FTP testing in a contractor-owned laboratory also in Mesa. In this respect, EPA's results have much greater applicability to the real world than results from recent "ASM" testing by Environment Canada [8], ARCO, California Air Resources Board, and the Colorado Department of Health.

The test procedures are discussed in detail in Appendix A.

[8] Vera F. Ballantyne, Draft, Steady State Testing Report and Data, Environment Canada, August 28, 1992.

4.

Data Description

From September 10, 1992 through March 19, 1993, EPA's contractor, Automotive Testing Laboratories (ATL), conducted a vehicle testing program in Mesa, Arizona, a suburb of Phoenix, on mostly 1983 and newer vehicles.

This program included several tasks designed to produce data for an analysis comparing the ASM test to the IM240 test as predictors of actual FTP emissions. These tasks included the operation of an Arizona I/M inspection lane. Vehicles at this lane received IM240s with a functional test of the evaporative canister purge system (referred to as the purge test in the remainder of this report), ASMs with the purge test, Arizona I/M tests, and fuel system pressure tests under real-world I/M testing conditions. In addition, vehicles were recruited from the I/M lane for additional tasks, which included:

- FTP laboratory testing
- IM240 laboratory testing
- Contractor IM240-targeted repairs
- Commercial repairs obtained by vehicle owners to pass the official Arizona I/M test.

Choosing vehicles for laboratory testing was driven by the importance of testing and assessing emissions from--and the impact of repair on--dirty in-use vehicles. A random sample of vehicles visiting the I/M station would result in the contractor recruiting mostly clean vehicles (see Section 5.2.5.8). But most excess emissions come from a relatively small percentage of vehicles known as high to super emitters. To avoid the problem and cost of evaluating a majority of vehicles that will ultimately be assessed as clean, a stratified recruitment plan was employed to deliberately over-recruit dirty cars, based on lane-IM240 results at the Mesa lane. A nominally 50/50 mix of IM240-clean and IM240-dirty vehicles were to be recruited for FTP exhaust testing. In actual practice, more dirty cars than clean have been recruited which is shown in Table 4.2.2.

Specifics concerning the recruitment criteria and the test procedures for these tasks are discussed in Appendix A.

4.1 Data Listings

Appendix B provides a listing of the data used for the cutpoint effectiveness analysis, the contractor repair analysis, and the commercial repair analysis, which are all discussed in Section 5.

Data for the over 1400 vehicles that only received one set of lane tests (no laboratory tests and no after-repair lane tests) are only available on disk. These data include the purge analysis data, and the lane data used to calculate ASM coefficients. The available disk(s) will include all IM240 and ASM lane data including lane data for the laboratory tested vehicles. These can be requested by contacting:

William M. Pidgeon
U.S. EPA
National Vehicle and Fuel Emissions Laboratory
2565 Plymouth Road
Ann Arbor, Michigan   48105-2425
Tel. No. 313-668-4416
Fax. No. 313-668-4497

Fax requests for data disks are preferred and a form is provided at the end of Appendix B; questions can be addressed by phone.

4.2 Database Statistics

The first official ASM/IM240 test series was run on September 9, 1992. Data collected up to March 17, 1993 were considered for these analyses. During that period, 1574 vehicles received 1758 ASM/IM240 test series at the Arizona I/M lane. Priority for testing was given to 1983 and newer model year fuel injected vehicles. The following table illustrates the model year and fuel metering distribution of the tested fleet:

Table 4.2.1
Lane Data By Model Year and Fuel Metering

MYR	PFI	TBI	CAR B	Totals
81	-	-	3	3
82	-	2	3	5
83	12	6	26	44
84	31	30	46	107
85	38	42	49	129
86	94	53	45	192
87	105	50	46	201
88	100	61	36	197
89	119	77	17	213
90	133	48	2	183
91	150	35	-	185
92	104	11	-	115
Totals	885	415	273	1574

Of the 1574 vehicles tested 27 were recruited for the commercial repair program and 127 vehicles were recruited to the laboratory for additional tests and for contractor repairs when the repair criteria were met (Section 5.6).

The following list summarizes the criteria used for recruiting laboratory vehicles and for data completeness:

- The IM240 and the ASM were designed to distinguish between malfunctioning and properly functioning newer technology cars, so only 1983 and newer fuel-injected (no carbureted) cars were used.

- One-half of the laboratory vehicles were to exceed 0.80/15.0/2.0 (HC/CO/NOx) on their lane-IM240.

- One-half of the recruited vehicles were to have the lane-IM240 performed prior to the ASM.

- Only vehicles having an as-received FTP, an as-received lane-IM240, and an as - received lane ASM test were used. Vehicles missing any one of these three tests were not included in the analysis.

The resulting database consisted of 106 fuel-injected. Table 4.2.2 lists actual distribution statistics for these laboratory vehicles.

Table 4.2.2
Distribution of Laboratory Recruited Vehicles

Lane-IM240	Fuel Metering	ASM Prior to IM240	IM240 Prior to ASM	Totals
Passed: ≤0.80 / 15.0 / 2.0	PFI	18	14	32
	TBI	5	3	8
Failed: >0.80 / 15.0 / 2.0	PFI	18	23	41
	TBI	14	11	25
Totals		55	51	106

Table 4.2.3 shows the model year and fuel metering distribution for the 106 laboratory recruited vehicles.

Table 4.2.3
Lab Data by Model Year and Fuel Metering

MYR	PFI	TBI	Totals
83	6	2	8
84	12	8	20
85	7	7	14
86	13	6	19
87	9	1	10
88	5	4	9
89	7	2	9
90	6	2	8
91	7	1	8
92	1	-	1
Totals	73	33	106

Table 4.2.4 provides FTP HC/CO emitter group statistics for these recruited vehicles. FTP emitter groups are defined based on FTP emissions as follows:

Normals:	HC<0.82	and	CO<10.2
Highs:	0.82≤HC<1.64	and	CO<13.6
		or	
	HC<1.64	and	10.2≤CO<13.6
Very Highs:	1.64≤HC<10.2	and	CO<150
		or	
	HC<10.2	and	13.6≤CO<150
Supers:	HC≥10.2	or	CO≥150

Table 4.2.4
Lab Vehicle FTP HC/CO Emitter Category Distribution

Normals	Highs	Very High	Supers
67	13	25	1

For more detailed information on the data used for these analyses refer to Section 5. For details on the data excluded from these analyses refer to Section 4.3 and Appendix C.

4.3 Quality Control (QC) Protocol

This Section provides a general description of the QC process. For more detailed descriptions of the QC criteria and data excluded from these analyses see Appendix C, which lists the QC criteria in detail and the vehicles removed due to the QC protocol.

Data were received from ATL in two forms. Calculated cycle-composite values for all tests (lab and lane), except the ASM tests, and second-by-second data for lane-IM240s and ASMs were provided. The calculated data and the raw second-by-second data followed separate but similar QC processes. The calculated data were processed using a program which performed checks on FTP data and IM240 (lab and lane) data. These checks included bag result comparisons, fuel economy checks, test distance checks, dynamometer setting checks, and test-to-test comparisons. For details on these checks see Appendix C.

The second-by-second data were processed by a separate program which performed similar checks for the raw data. The QC checks for the second-by-second data included checks for acceptable speed, correct test/mode duration, sampling continuity, reasonable ambient background concentrations, acceptable purge flow, and reasonable fuel economy. Again details concerning these QC criteria are included in Appendix C. The second-by-second QC program also calculated composite values for the IM240 and ASM tests.

In addition to the QC program comparisons, the calculated results reported by ATL were compared to those results calculated from the second-by-second data. Significant differences were investigated. All lab vehicles violating the QC criteria were hand checked by EPA staff and the data were corrected or removed, as warranted. Due to the volume of lane data, lane vehicles that violated QC tolerances were removed from all pertinent analyses, without further attempts to “save” the data unless solutions were obvious. These unutilized data will be checked, as time permits, for future use. In contrast, because the vehicles that received FTPs were relatively precious, significant effort was expended to correct data that were identified by the QC process.

Vehicles removed from the sample are discussed in Appendix C on page C-4 through C-8.

5. Analyses/Discussion

5.1 Introduction

The purpose of Section 5 is to present the analysis EPA used to assess whether the ASM test is sufficiently effective in identifying high emitting cars needing repair when compared to the IM240 test, and the findings of that analysis. Additionally, it provides a comparison of the repair issues for those vehicles that were identified as needing repairs.

Section 5.3 compares the ability of the ASM and the IM240 to identify vehicles needing repair, and presents EPA's major findings regarding the effectiveness of the ASM as an alternative to the IM240 for enhanced I/M programs. It discusses comparisons of IM240 versus ASM using information from cutpoint tables. Section 5.2 provides information needed to understand how the cutpoint tables were derived.

Section 5.4 compares the correlation of the IM240 and ASM with the FTP using traditional regression analysis. Section 5.5 discusses the somewhat specialized issue of how four ASM scores are combined in one score and the uncertainties and sensitivities in this process.

Section 5.6 discusses the repairs performed by the contractor and repairs performed by commercial repair shops.

Section 5.7 discusses canister purge system test results and Section 5.8 discusses methods that will be explored to improve the power of the IM240.

5.2 Analyses Techniques

This section discusses the methodology and criteria EPA used to compare the ability of the ASM and the IM240 to identify vehicles needing repair. This section explains why the criteria are important, how the criteria are derived, and indicates the tradeoffs associated with these interrelated criteria. Then, Section 5.3 contrasts the ASM and the IM240 using the criteria explained in Section 5.2.

5.2.1 Reducing Four Steady-State Modes to a Single Score per Pollutant For Comparison to One Cutpoint per Pollutant

This section explains how the final ASM score is computed. Two questions will be answered in this section:

1. Should the four mode scores for each pollutant be combined to calculate a single result or score for each pollutant, or should a separate score be reported for each of the four modes, and apply those separate scores to separate cutpoints for each of the four modes?

2. How is the score computed for each ASM mode?

5.2.1.1 Reporting Overall ASM Results Versus Reporting Individual Mode Results

There are three alternatives for reporting overall ASM test results. The first alternative does not combine the scores from the separate modes, so this alternative is analogous to the way 2500/idle test results are reported. The HC and CO scores are reported for the 2500 mode and separate HC and CO scores are reported for the idle mode for a total of four scores and up to four cutpoints. For the four mode ASM test, this is too complicated. With NOx added, three cutpoints are needed for the 3 dynamometer modes and two cutpoints (HC and CO only) for the idle mode, necessitating 11 separate cutpoints. (Because NOx emissions are insignificant during an idle test, NOx is only considered for the 3 dynamometer modes.) This first alternative is too unwieldy for a four mode test.

The second and third alternatives are two different ways to report a single score for each pollutant by combining one pollutant’s scores from all the modes.

For the second alternative, the single score would be the sum of the scores from each mode, using a weighting of 25% for each mode. For example, to calculate the single ASM score for HC, the equation would be as follows:

$$\text{ASM HC} = (0.25 * 5015\ \text{HC}) + (0.25 * 2525\ \text{HC}) + (0.25 * 50\text{RL HC}) + (0.25 * \text{idle HC})$$

In the third alternative, which EPA used, a single score is determined from the sum of the individual mode scores, but the weighting or coefficient for each was determined by regression techniques. A multiple regression was performed wherein all four of the mode scores are independent variables that were regressed against FTP scores. The regression produced coefficients for each mode, plus a constant. These coefficients weight each mode more appropriately than the second alternative’s method of just assigning each mode a weighting of 25%. BAR/Sierra used this regression method, and likewise EPA’s analyses for this report also used this regression method, with one difference that is discussed in Section 5.5. This yields an equation to calculate a single ASM score for each pollutant. For example, the equation for calculating a single ASM HC score is as follows:

$$\text{ASM HC} = (x * 5015\ \text{HC}) + (y * 2525\ \text{HC}) + (z * 50\text{RL HC}) + (t * \text{idle HC}) + \text{Constant}$$

the x, y, z, t, and constant terms are listed in Table 5.2.2.

While ASM advocates have used this concept, none have proposed specific coefficients for EPA to evaluate. Thus, EPA had to develop coefficients.

The remaining question is: “How were each of the individual mode scores determined?”

5.2.1.2 Determination of Individual Mode Scores

Emission concentrations were measured on each of the four ASM modes (see Section 5.2.3 for more details). These concentration measurements were then converted to simulated grams/mile emissions, because concentration measurements do not provide a reliable indication of the magnitude of pollutants emitted per mile traveled. At the same exhaust concentration level, a heavy vehicle will emit more per mile than a light vehicle.

To calculate simulated g/mi results, EPA followed BAR/Sierra's method, which was also followed by ARCO, wherein the measured concentration values are multiplied by the Inertia Weight (engine displacement for the idle mode) of the vehicle. *The Idle Mode was not considered for NOx since it is a no load test.* EPA also divided these simulated g/mi results by the scaling factors listed in Table 5.2.1. Using these factors yield overall ASM scores that have magnitudes similar to FTP and IM240 magnitudes.

Table 5.2.1: Scaling Factors Used to Keep Regression Coefficients of Equal Magnitude

Pollutant	Modes 1-3 [CONC] * IW / x	Mode 4 [CONC] * Disp(L) / x
HC	10^5	10^3
CO	10^2	10^0
NOx	10^6	NA

5.2.2 Multiple Linear Regressions to Find ASM Coefficients

As previously discussed, multiple linear regressions were performed using the four modes (three for NOx) of the ASM test as the independent variables (X1,...,X4) The one difference mentioned in Section 5.2.1.1 above is that the IM240 (rather than the FTP) was used as the dependent (Y) variable *. This was done for tests on which the ASM was run first only, because the corresponding IM240s are pre-conditioned, and thus more closely resemble an FTP.

Vehicles that were recruited to the lab or received commercial repairs were not included in the database used to develop coefficients, because these are the cars to which the coefficients were applied. EPA determined that including these would cause the developed coefficients to mask the test variability of the ASM. (This is also discussed in Section 5.5.)

---

* Why the IM240 was used as the dependent variable, rather than the FTP, is explained in Section 5.5. This is not discussed here because the purpose of this section is to explain how, rather than why. Also, this issue requires a lengthy discussion and relies on information presented in Section 5.5, so repetition is also avoided.

The multiple linear regressions were run on a database of 608 lane ASM tests versus pre-conditioned lane-IM240s, giving the following coefficients for each mode.

Table 5.2.2
Coefficients Developed from Multiple Regression ASM Versus IM240
(see Table 5.2.1 for scaling factors)

Mode	HC	CO	NOx
Constant	0.083	2.936	0.258
5015	0.025	0.040	0.061
2525	0.059	0.043	0.219
50 MPH	0.136	0.356	0.352
Idle	0.124	1.350	NA
Adjusted R^2	29.0%	50.1%	59.1%

5.2.3 Applying ASM Coefficients

The coefficients were then used to calculate composite ASM scores for all lab vehicles and commercially repaired vehicles. These are the ASM scores that are reported in the ensuing cutpoint tables, scatterplots, and regressions.

5.2.4 ASM Concentration Measurements

The ASM concentrations were measured over a 40 second period. Because the exhaust sample delay to the most downstream analyzer cell is almost 10 seconds, the first 10 seconds of data were ignored. The concentrations that are used in the composite ASM score calculations are actually reported averages over the last 30 second period. For various reasons, the time allotted for measured concentrations was occasionally less than 30 seconds. In these few cases, EPA calculated the average concentrations over this shortened period and reported these values. No ASM tests were accepted with concentrations averaged over a period of less than 20 seconds.

5.2.5 Explanation of the Criteria Used To Compare I/M Tests

In assessing the overall effectiveness of the ASM relative to the IM240, it is important to determine their effectiveness in measuring and determining a variety of factors, including the excess emissions identified, the failure rate, the error-of-commission rate, the two-ways-to-pass criteria, the discrepant failures, and the unproductive failure rate. Each of these is discussed below. These criteria are used in Section 5.3 to compare the effectiveness of the two procedures.

5.2.5.1 Excess Emission Identification Rate (IDR)

EPA commonly uses the rate of excess emissions identified during an I/M test to objectively and quantitatively compare I/M test procedures. Excess emissions are those FTP-measured emissions that exceed the certification emission standards for the vehicle under consideration. For example, a vehicle certified to the 0.41 g/mi HC standard whose FTP result was 2.00 g/mi, would have excess emissions equalling 1.59 g/mi HC (i.e., 2.00 - 0.41 = 1.59).

The excess emissions identification rate (IDR) equals the sum of the excess emissions for the vehicles failing the I/M test divided by the total excess emissions (because of imperfect correlation between I/M tests and the FTP, some I/M passing vehicles also have excess emissions which are used for calculating the total excess emissions). Thus, assuming an I/M area that tests 1000 vehicles, 100 of which are emitting 1.59 g/mi excess emissions each, while the I/M test fails (identifies) 80 of the excess emitting vehicles, the excess emission identification rate can be calculated as follows:

$$\frac{\text{80 failing vehicles * 1.59 g/mi excess per vehicle}}{\text{100 vehicles * 1.59 g/mi excess per vehicle}} \text{ * 100 = 80\% IDR}$$

EPA uses IDR instead of merely comparing the number of vehicles that correctly fail and correctly pass. The IDR better contrasts the relative merits of competing I/M test procedures because failing vehicles with high emissions is more important than failing those that are only slightly above their certification standards. For example, take two I/M procedures that correctly failed 100 of the 500 vehicles that had FTP emissions greater than their certification standards, but only 50 cars failed both tests. If the fifty cars that failed Test A were high FTP emitters, and the other 50 cars that failed Test B had FTP emissions only slightly above their standards, obviously Test A would be preferred, and its IDR would reflect its better performance. Test A’s better performance is not evident in comparing the number of vehicles that correctly fail.

5.2.5.2 Failure Rate

As the IDR increases with different test procedures or different cutpoints, the opportunity to identify vehicles for emission repairs also increases. However, this measure is not sufficient for determining which is the more efficient and cost-effective I/M test. Other criteria must also be addressed before such an assessment can be made. One such criterion is the failure rate, which is calculated by dividing the number of failing vehicles by the number of vehicles tested. For example:

$$\frac{\text{50 vehicles failed I/M}}{\text{1000 vehicles tested}} \text{ * 100 = 5\% I/M failure rate}$$

The ideal I/M test is one that fails all of the dirtiest vehicles while passing those below the FTP standard or close to it but still above it. The potential emission reduction benefit decreases as emission levels from a vehicle approach the standard, because the prospect for effective repair diminishes. Thus, achieving a high IDR in conjunction with a low failure rate (as a result of identifying fewer vehicles passing or close to the standard) efficiently utilizes resources.

5.2.5.3 Error-of-Commission (Ec) Rate

Properly functioning vehicles which pass FTP standards sometimes fail the I/M test; these are referred to as false failures or errors-of-commission (Ecs). When error-of-commission vehicles are sent to repair shops, no emission control system malfunctions exist. Often, the repair shop finds that the vehicle now passes the test without any changes. These false failures waste resources, annoy vehicle owners, and may lead to emissions increases as a result of unnecessary and possibly detrimental "repairs." Automobile manufacturers see this as a significant problem, since it can contribute to customer dissatisfaction and increased warranty costs. An I/M program seeking larger emission reductions through more stringent emission test standards may actually increase the number of false failures. The error-of-commission rate is, therefore, an important measure for evaluating the accuracy of I/M tests.

To see how an error-of-commission rate is calculated, assume an I/M area which tests 1000 vehicles, of which 100 fail the I/M test, although only 50 of those 100 failing vehicles also exceed the FTP standards. The error-of-commission rate equals the number of vehicles that fail the I/M test while passing the FTP divided by the total number of vehicles which were I/M tested:

$$\frac{\text{50 vehicles failed I/M but passed FTP}}{\text{1000 vehicles tested}} * 100 = \text{5\% Ec rate}$$

As the error-of-commission rate decreases, vehicle owner satisfaction and acceptance of the I/M program increases. Thus, while it is relatively easy to improve the IDR by making the I/M test standards more stringent, this “improvement” comes at the cost of potential increases in the error-of-commission rate.

5.2.5.4 Two-Ways-To-Pass Criteria

The theory behind the two-ways-to-pass criteria for the IM240 is as follows. Assuming that the IM240 test was correctly performed in the first place, the most likely reason that a properly functioning vehicle would fail an IM240 is that the evaporative canister was highly loaded with HC molecules and that they were being purged into the engine during the test. This has been a significant cause of false failures in existing I/M programs and it has been shown that highly loaded canisters can cause both high HC and CO emissions, even though the feedback fuel metering system is functioning properly.

Since the canister is being purged during the IM240, the fuel vapor concentration from the canister continually decreases during IM240 operation. The decreasing fuel vapor concentration results in decreasing HC and CO emissions. So, emissions during Mode-2 (the last 136 seconds of the 239 second cycle) should be lower than the composite results. On the other hand, if the vehicle is actually malfunctioning, Mode-2 emissions should remain high.

Catalyst temperature can also affect test outcome. Emissions are generally highest after a cold start, before the catalyst has had a chance to warm up. If a vehicle is standing in line for a prolonged period of time, or was not sufficiently warmed up before arriving at the test lane, this can cause the vehicle to fail, when, in fact, it should be passed. Under the two-ways-to-pass criteria, Mode-1 acts as a preconditioning mode, thus providing insurance against this particular variety of false failure.

NOx cutpoint criteria are not included in EPA's two-ways-to-pass algorithm. So a vehicle which meets the IM240 NOx cutpoint (i.e., composite NOx $\leq$ 2.0) only fails if both its composite emissions exceed the HC or CO composite cutpoints, and its Mode-2 emissions exceed the HC or CO Mode-2 cutpoints. In other words, a vehicle can pass by having low HC/CO emissions in Mode-2 even if its Mode-1 HC/CO emissions were high. EPA is mandating this approach to IM240 cutpoints.

The IM240 cutpoint tables, in Appendix E and Table 5.3.1 in the next section, were calculated using the two-ways-to-pass-criteria.

The two-ways-to-pass criteria were optimized **only** at the cutpoints EPA recommends for biennial enhanced I/M programs, which are referred to as "standard" or "recommended" IM240 cutpoints. For composite emissions, the standard cutpoints are 0.80 g/mi HC, 15.0 g/mi CO and 2.0 g/mi NOx. The Mode-2 criteria for the standard cutpoints are 0.50 g/mi HC and 12.0 g/mi CO. The Mode-2 cutpoints were carefully selected from EPA's IM240 data collected in Indiana, to pass properly functioning vehicles while continuing to fail malfunctioning vehicles. (The Mode-2 criteria were not redetermined for this new Arizona sample.) The Mode-2 criteria, listed in the cutpoint tables in Appendix F and Table 5.3.1, simply increase proportionally with increasing composite cutpoints (i.e., become less stringent) and decrease proportionally with decreasing composite cutpoints (i.e., become more stringent). The point is that these Mode-2 criteria have not been optimized at every stringency level to provide the best tradeoff among IDR, failure rate, and Ecs, so it is probable that the effectiveness of the IM240 Mode-2 cutpoints can be improved.

5.2.5.5 Discrepant Failures (DFs)

Discrepant failures are vehicles that fail an I/M test for HC and/or CO and pass the FTP for HC and CO, but fail the FTP for NOx, or vice versa. The table below illustrates one possible discrepant failure scenario:

Test	HC or CO	NOx
Short Test	Pass	Fail

FTP	Fail	Pass

In this example, a false failure for NOx happens to occur on a vehicle which is a false pass for HC/CO.

Repair diagnostic routines are frequently selected on the basis of which pollutant caused the I/M test failure. Given that HC/CO and NOx move in opposite directions with changes to the A/F ratio, there is not much reason to expect that fixing a NOx problem will reduce HC/CO emissions. Therefore, these scenarios represent an error of sorts for the short test. If a vehicle was to fail the short test for NOx, whereas the only high FTP pollutant was CO, chances are the mechanic will be looking for a problem that causes high NOx. In this case, the problem that is causing high CO emissions is not likely to be found.

5.2.5.6 Unproductive Failure (UF) Rate

The unproductive failure rate represents the percentage of vehicles that will be identified as needing repair, but either repair is not needed (Ecs), or it is not likely the reason for repair will be found (DFs). The unproductive failure rate is calculated by adding errors-of-commission to discrepant failures, and dividing the quantity by the total number of vehicles which were I/M tested. Keeping with the same example as above, take an I/M area which tests 1000 vehicles. 100 fail the I/M test, 50 of those 100 failing vehicles are Errors-of-Commission, and 5 are Discrepant Failures:

$$\frac{50\ \text{Ecs} + 5\ \text{DFs}}{1000\ \text{vehicles tested}} * 100 = 5.5\%\ \text{UF}^{*}\ \text{rate}$$

*Unproductive Failure

5.2.5.7 Vehicles with Malfunctions That Were Not Counted as Ecs and DFs

Errors-of-commission in I/M programs have been most often caused by test-to-test variability or incompatibility between the I/M test procedure and vehicle emission control systems (e.g., air pump switching), so attempting to repair Ec vehicles were fruitless. With the IM240, however, EPA has found that some vehicles that had failed the IM240 and passed the FTP actually did have malfunctions, so they were correctly identified and air quality would suffer by ignoring them. By the strict definition of Ecs, the IM240 is penalized despite its successfully identifying malfunctioning vehicles.

A likely reason for vehicles passing the FTP despite a malfunction is that malfunctions are sometimes intermittent. Vehicle 3172 provides a good example. This vehicle had a number of IM240s performed, some with high NOx and others with low NOx. The mechanic indicated that the vehicle had a sticky EGR valve. The mechanic’s diagnosis was not influenced by the FTP result because the contractor had been instructed to report only IM240 scores to the mechanics, not the FTP score. This has become standard practice to allow the contractor-repairs to simulate commercial repairs, where mechanics will not have access to FTP results.

For this analysis, EPA did not count vehicles as Ecs when they had a malfunction that would logically explain the IM240 test failure. To facilitate a fair comparison between the ASM and the IM240, the ASM failing vehicles that passed the FTP, but had malfunctions, also were not counted as Ecs when their malfunction would logically explain the ASM failure.

EPA was very conservative in that a vehicle was counted as an Ec unless the malfunction clearly explained the ASM or IM240 test failure. For example, vehicle 3239 failed the IM240 with 2.4 g/mi NOx yet passed the FTP. The vehicle was diagnosed as having a slow responding O2 sensor and it was replaced. Because (1) a report of a slow-responding O2 sensor does not indicate that objective criteria were used, (2) NOx failures are not strongly associated with defective O2 sensors, and (3) all of its other IM240 tests had passing NOx, the car was counted as an Ec despite the mechanic's judgement the the O2 sensor should be replaced, which he did.

Using the similar logic, some vehicles with discrepant failures were also not counted as DFs when their malfunctions could logically explain the I/M test failure and a proper repair could be expected to reduce FTP emissions of the affected pollutant even though FTP emissions of that pollutant were initially below FTP standards. For example, the vacuum leaks on vehicle 3154 could cause a lean air/fuel ratio which can lower the catalyst's NOx conversion efficiency and cause higher combustion temperatures, both of which can cause high NOx on the IM240 and ASM. FTP NOx emissions should also be affected but perhaps not enough to cause an FTP failure. Because it is logical for a mechanic to check for vacuum leaks on a car that fails NOx, and this vehicle did have vacuum leaks, the I/M tests shouldn't be penalized for correctly identifying the malfunction. On the other hand, if this vehicle had failed CO on an I/M test and NOx on the FTP, the mechanic would look for problems causing a rich air/fuel ratio, which would probably preclude looking for vacuum leaks.

Table 5.2 lists the five vehicles the met the strict definitions for Ecs or DFs, but were not counted for the reasons discussed. *Note that while these vehicles were not counted as Ecs or DFs in the cutpoint tables, they still do count toward the Failure Rate.*

Table 5.2.3.1: Cars not Counted as Ecs or DFs

Vehicle	Original Status	Malfunctions Explaining I/M Test Failure
3154	*Discrepant Failure*; failed IM240 and ASM NOx, but failed FTP CO only.	Injector seals leak at intake manifold; distributor advance vacuum hose broken.
3172	*Error-of-Commission;* IM240 NOx.	EGR valve sticks, EGR valve vacuum line plugged.
3200	*Discrepant Failure*; failed IM240 and ASM NOx, but failed FTP HC only.	EGR position sensor out of range.
3216	*Error-of-Commission;* ASM HC	ECM malfunction
3244	*Error-of-Commission;* IM240 and ASM NOx.	Injector malfunctions intermittently.

5.2.5.8 Weighting Factors to Correct Biased Recruiting

The criteria used to recruit vehicles for laboratory testing heavily biased this laboratory sample toward IM240 failing vehicles. Sixty-two percent of the 106 laboratory vehicles had failed the lane-IM240 criteria (>0.80/15.0/2.0), whereas only 19% of 2,070 cars tested at the lane failed the IM240. This resulted in a laboratory sample that was highly biased toward failing vehicles. (Two-ways-to-pass criteria was not considered for laboratory recruiting.)

Using this biased database results in unrealistically high excess emission identification rates, and unrealistically low error-of-commission rates. So the laboratory database must be corrected to represent the pass/fail vehicle ratio in the in-use fleet to correctly determine IDRs, failure rates, and Ecs. The database was corrected using the weighting factors presented in Table 5.2.5.2.

Weighting factors are used as follows: If the 66 failing vehicles that received FTP tests had excess HC emissions which totaled 100 g/mi, the database would be corrected in this case by multiplying 100 by the 5.97 weighting factor, resulting in corrected total excess emissions of 597 g/mi for the dirty vehicles. In comparison, the total excess emissions of the IM240-clean vehicles have to be multiplied by 41.9 to make their excess emissions representative. The total simulated excess emissions are the sum of the simulated excess emissions from the clean and dirty vehicles in the I/M lane sample. The number of vehicles tested was similarly adjusted with the factors for the purpose of calculating failure rates. The sample of 40 clean vehicles provides confidence in conclusions about a test's relative tendency to avoid failing clean cars.

Table 5.2.5.2
Weighting Factors Used To Adjust the Laboratory Database

	IM240 at Lane	# at Lane	# at Lab	Weighting Factor
Pass:	≤0.80/15.0/2.0	1676	40	41.90
Fail:	>0.80/15.0/2.0	394	66	5.97

The resulting weighted database was used to produce the realistic estimates of IDRs, failure rates, and Ecs that are listed as cutpoint tables in Appendices D & E. These cutpoint tables are sorted by failure rates. For the cutpoints that produce the same failure rate, the results are sorted first by HC IDRs (in descending order) and then by NOx IDRs.

5.3

Comparison of IM240 Versus ASM Using Cutpoint Tables

In assessing the overall effectiveness of I/M test procedures, as discussed in Section 5.2, it is important to determine the test's effectiveness in terms of IDR, the failure rate, discrepant failures and unproductive failure rate.

Appendices D and E list the same criteria for many different cutpoints. Table 5.3.1 provides a summary of these criteria to compare the ASM with the IM240 for the following three important scenarios:

- ASM cutpoints selected to achieve the same 18% failure rate (using the cutpoint tables that are reweighted to correct the lab sample bias) that result from EPA’s recommended IM240 two-ways-to-pass cutpoints of .80/15.0/2.0 + 0.50/12.0. Among the ASM cutpoint combinations with this failure rate (see Appendix E), a combination was selected that produced the maximum IDRs for all the pollutants simultaneously, so there was no need to set priorities among pollutants.

- ASM cutpoints selected to achieve IDRs similar to the IDRs that result from EPA ’s recommended IM240 two-ways-to-pass cutpoints of .80 / 15.0 / 2.0 + 0.50 / 12.0. Because ASM CO and NOx IDRs could more favorably be presented by excluding HC, two ASM cutpoint sets are presented, one to provide matching ASM and IM240 HC IDRs (resulting in better IDRs for CO and NOx), and the second to provide matching ASM and IM240 CO & NOx IDRs.

- ASM and IM24O cutpoints selected to achieve the highest IDRs possible while keeping the unproductive failure rate below 5%. This case was addressed on the possibility that an aggressive I/M program might be willing to operate with such a high Ec rate.

Table 5.3.1
Comparison of the Ability of IM240 and ASM to Identify Vehicles Whose Emissions Exceed Certification Standards Based on 106 Lab Vehicles Weighted to Represent 1676 Lane Vehicles

Test	Scenario	Failure Rate	Excess Emissions Identified HC	CO	NOx	Ec*	Discrepant Failures	Unproductive Failure Rate**	Cutpoints
		%	%	%	%	#	#	%	
IM240	Standard Ctpts.	**18**	92.2	67.5	83.4	0	12	0.6	.80 / 15.0 / 2.0 + 0.50 / 12.0
ASM	Same Fail Rate	**18**	74.7	61.1	68.0	42	6	2.3	1.00 / 8.0 / 2.0
ASM	Similar HC IDR	**42**	92.4	78.1	95.0	174	180	17.1	1.00/8.0/1.0
ASM	Similar CO & NOx IDRs	**24**	80.4	66.2	89.4	84	48	6.4	1.00/11.0/1.4
ASM	Best IDRs w/UF @ <5%	**28**	82.5	67.0	80.1	48	48	4.6	.40 / 8.0 / 1.5
IM240	Best IDRs w/UF @ <5%	**33**	95.9	78.2	97.1	60	12	3.5	.30 / 9.0 / 1.7 + .19 / 7.0
	Weighted # of Vehicles =	1676							

* Excludes Ec vehicles that had malfunctions that caused an I/M test failure, but because they were intermittent malfunctions, did not fail the FTP. FTPs were always performed on a different day. Since they were correctly identified by the I/M test, they are not vehicles that will "ping-pong".

** The Unproductive Failure Rate includes the traditional Ec vehicles and the discrepant failures, without including the traditional Ec vehicles that were found to have intermittent malfunctions that were not identified by the FTP test.

For the first scenario with an 18% failure rate for both tests, the ASM statistics in Table 5.3.1 show that the IM240 identifies 18 percentage points more of the excess HC emissions and 15 percentage points more of the excess NOx emissions than the ASM identifies, with a significantly lower unproductive failure rate. Expressed differently, an IM240-based program would relinquish about 19% of its HC effectiveness and 18.5% of its NOx effectiveness by substituting the ASM test at the same failure rate. Some relatively dirty vehicles are missed by the ASM and replaced by relatively clean vehicles. This scenario is illustrated in Figure 5.3.1.

The second scenario shows that in order to achieve HC IDRs similar to the IM240's at an 18% failure rate, the ASM's failure rate must be increased to 42%, resulting in an unacceptable Ec rate of 17%. To achieve similar CO and NOx IDRs with the ASM, an ASM failure rate of 24% is necessary, and that also results in an unacceptable unproductive failure rate of 6.4%. This scenario is illustrated in Figures 5.3.2 and 5.3.3.

The last scenario compares the tests at the maximum IDRs achievable while limiting the unproductive failure rate to less than five percent. Again, the IM240 IDRs are significantly higher than the ASM's, with a lower unproductive failure rate. The IM240 HC IDR is 14% higher, the CO IDR is 14.3% higher, and the NOx IDR is 17.5% higher, with an Ec rate that is 1% lower. Expressed differently, an aggressive IM240-based program with a 3.5% unproductive failure rate would relinquish about 14% of its HC and 17.5% of its NOx effectiveness by substituting the ASM test at at an even higher unproductive failure rate. This scenario is illustrated in Figure 5.3.4.

These statistics indicate that the ASM test is significantly less effective than the IM240 as an I/M test.

The second scenario, wherein the ASM's HC IDR is raised to match the IM240's HC IDR of 92%, is anticipated to raise the following question:

> Why didn't EPA make the ASM's HC cutpoint more stringent to increase the ASM's IDR without increasing the stringency of the ASM's NOx cutpoint, thereby allowing a lower ASM failure rate?

The answer is that eight vehicles (see Table 5.3.2) have a major impact on the ASM HC IDR, but their ASM HC scores are less than 0.3 g/mi. Although their ASM HC scores are very low, they account for roughly 10.5% of the total excess FTP HC emissions. These eight vehicles also have ASM CO scores below 8.0 g/mi. While developing the ASM cutpoint tables, EPA found that ASM cutpoints below 0.3/8.0 caused failure rates and Ecs to increase excessively, so the final cutpoint tables did not include tighter cutpoints. So to achieve the IM240's HC IDR, the only "practical" way to identify these cars is through the NOx cutpoint.

Five of the eight cars with high FTP HC that pass the ASM HC cutpoints are failed by a NOx cutpoint of 1.5 or less. These five cars account for 7.6% of the total excess HC emissions. So the 1.0 g/mi ASM NOx cutpoint achieves an HC IDR comparable to the 92.2% achieved by the IM240 at EPA's standard cutpoints.

Table 5.3.3 summarizes the ASM cutpoint table in Appendix E to show that the only way for the ASM to achieve the IM240's HC IDR of 92.2% at the recommended cutpoints for biennial programs is to lower the ASM NOx cutpoint to 1.0.

Table 5.3.2: Vehicles that Pass a 0.30 g/mi ASM HC Cutpoint While Failing FTP HC

Vehicle	HC FTP	CO FTP	NOx FTP	HC ASM	CO ASM	NOx ASM
3180	0.96	9.75	1.22	0.15	3.64	0.68
3192	0.49	6.31	0.53	0.20	6.42	0.92
3195	0.51	5.80	0.66	0.18	3.26	1.27
3199	0.53	10.90	1.53	0.29	3.89	1.53
3201	0.94	19.73	1.72	0.17	4.73	1.22
3254	1.87	35.87	1.16	0.29	7.37	1.13
3257	1.26	8.57	0.90	0.25	4.65	1.03
3259	1.94	14.95	0.53	0.23	4.61	1.22

Table 5.3.3: Alternative ASM Cutpoints For High HC IDRs

ASM	Identification Rates			Failure	Ec	Discrepant	UF
Cutpoints	HC	CO	NOx	Rate	Rate*	Failures	Rate
0.30 / 8.0 / 2.0	88.0%	69.2%	74.9%	29%	4.3%	0	4.3%
0.30 / 8.0 / 1.8	88.2%	69.3%	78.2%	30%	4.3%	0	4.3%
0.30 / 8.0 / 1.5	89.0%	71.0%	82.7%	33%	4.3%	42	6.4%
0.30 / 8.0 / 1.4	90.3%	75.1%	89.5%	38%	6.4%	42	8.4%
0.30 / 8.0 / 1.3	90.3%	75.2%	89.5%	40%	6.4%	84	10.4%
0.30 / 8.0 / 1.2	91.4%	76.4%	89.9%	42%	6.4%	126	12.4%
0.30 / 8.0 / 1.0	96.6%	82.1%	95.0%	48%	8.7%	132	15.0%
0.40 / 8.0 / 1.0	92.4%	78.8%	95.0%	45%	8.7%	138	15.3%
1.00 / 8.0 / 1.2	84.1%	71.9%	89.8%	32%	4.0%	132	10.4%
1.00 / 9.0 / 1.0	91.3%	74.9%	95.0%	40%	8.4%	221	19.1%
1.00 / 8.0 / 1.0	92.4%	78.1%	95.0%	42%	8.4%	180	17.1%

To achieve an HC IDR rate greater than 89% a NOx cutpoint of less than 1.5 is necessary. To achieve an HC IDR rate greater than 91.4% a NOx cutpoint of less than 1.2 is necessary, and to achieve an HC IDR rate greater than 92% a NOx cutpoint of 1.0 is necessary. Once a tight NOx cutpoint is used to fail these cars with excess HC, the HC cutpoint no longer determines the result, at least in this sample. So, ASM cutpoints of 1.00/8.0/1.0 are the least stringent ASM cutpoints that can achieve a 92% HC IDR.

Another consideration is that the ASM cutpoints have been optimized for this database. In contrast, the IM240 recommended cutpoints were optimized for the Indiana IM240 database. Because of sample to sample differences, the optimum cutpoints are expected to vary slightly from one database to another. So the optimum ASM cutpoints are being compared to standard IM240 cutpoints, which while optimum for the Indiana data, are not the optimum cutpoints for this database. Applying ASM cutpoints optimized for this data base, to a different database, is expected to further lower the ASM's performance.

Figure 5.3.1
Comparison of ASM to IM240
Using IM240 Standard Cutpoints
With Maximum ASM IDRs at Equivalent Failure Rates

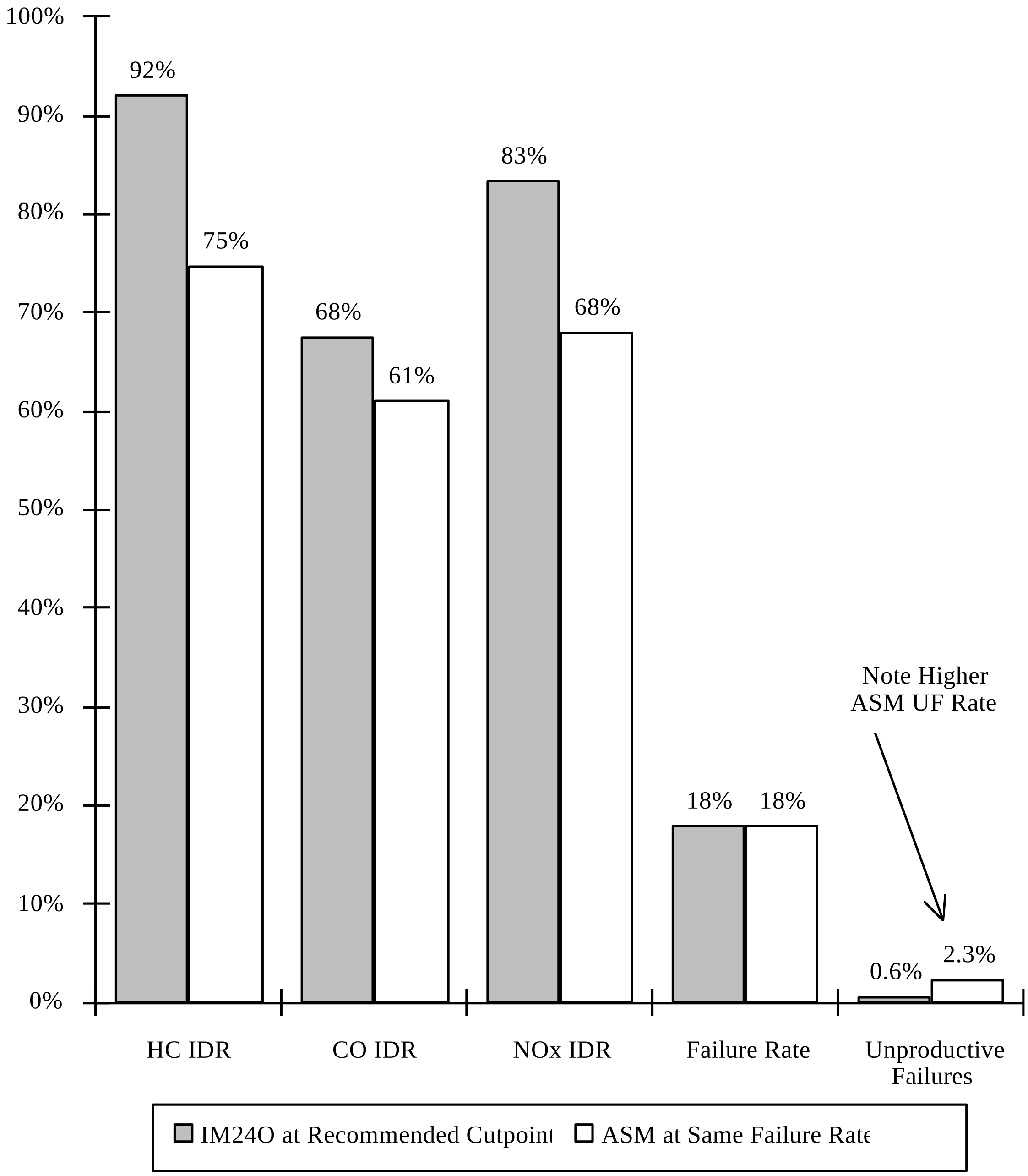


Figure 5.3.2
Comparison of ASM to IM240
With ASM HC IDR Matching IM240 IDF

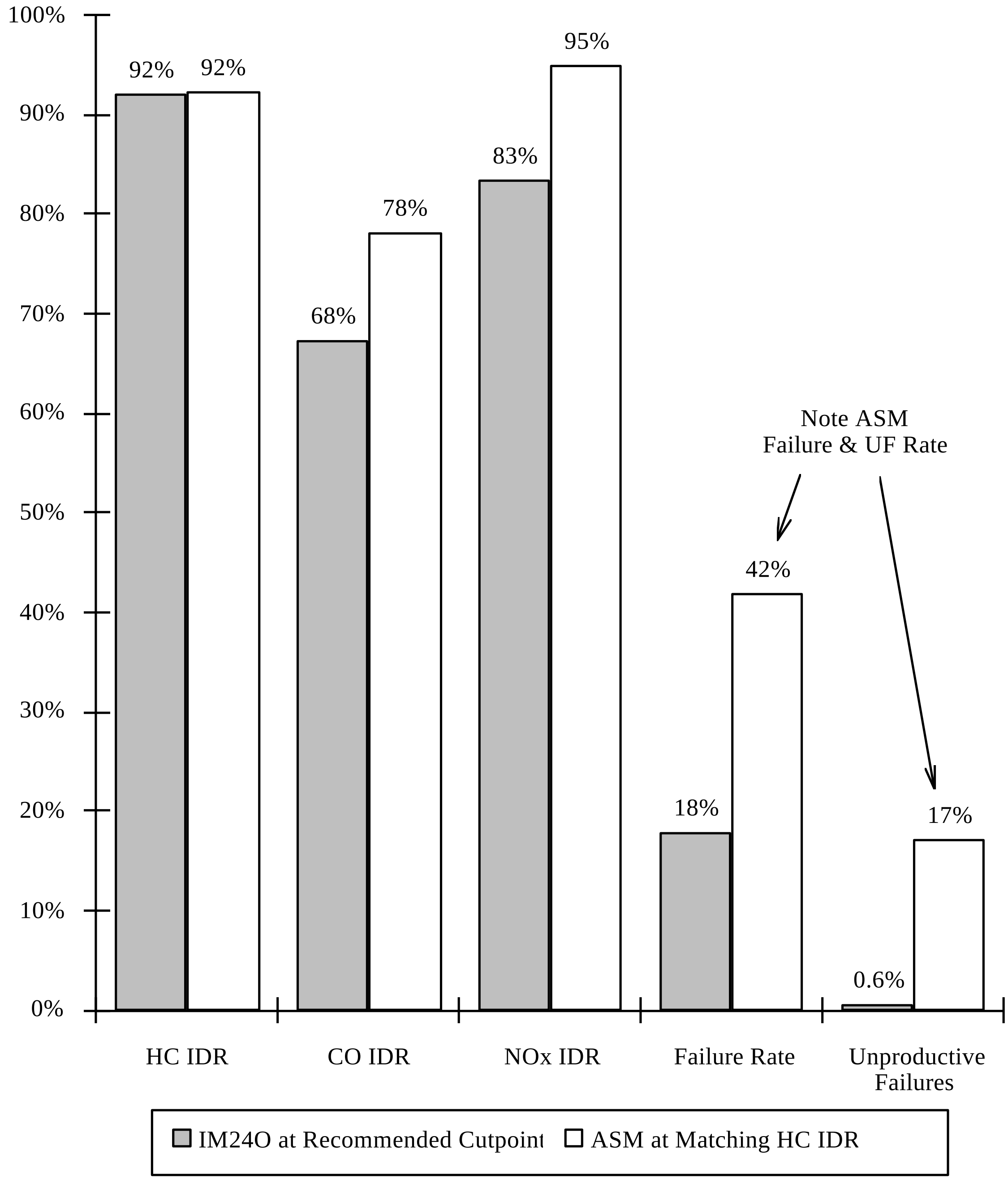


Figure 5.3.3
Comparison of ASM to IM240
With ASM CO & NOx IDRs Matching IM240 IDR

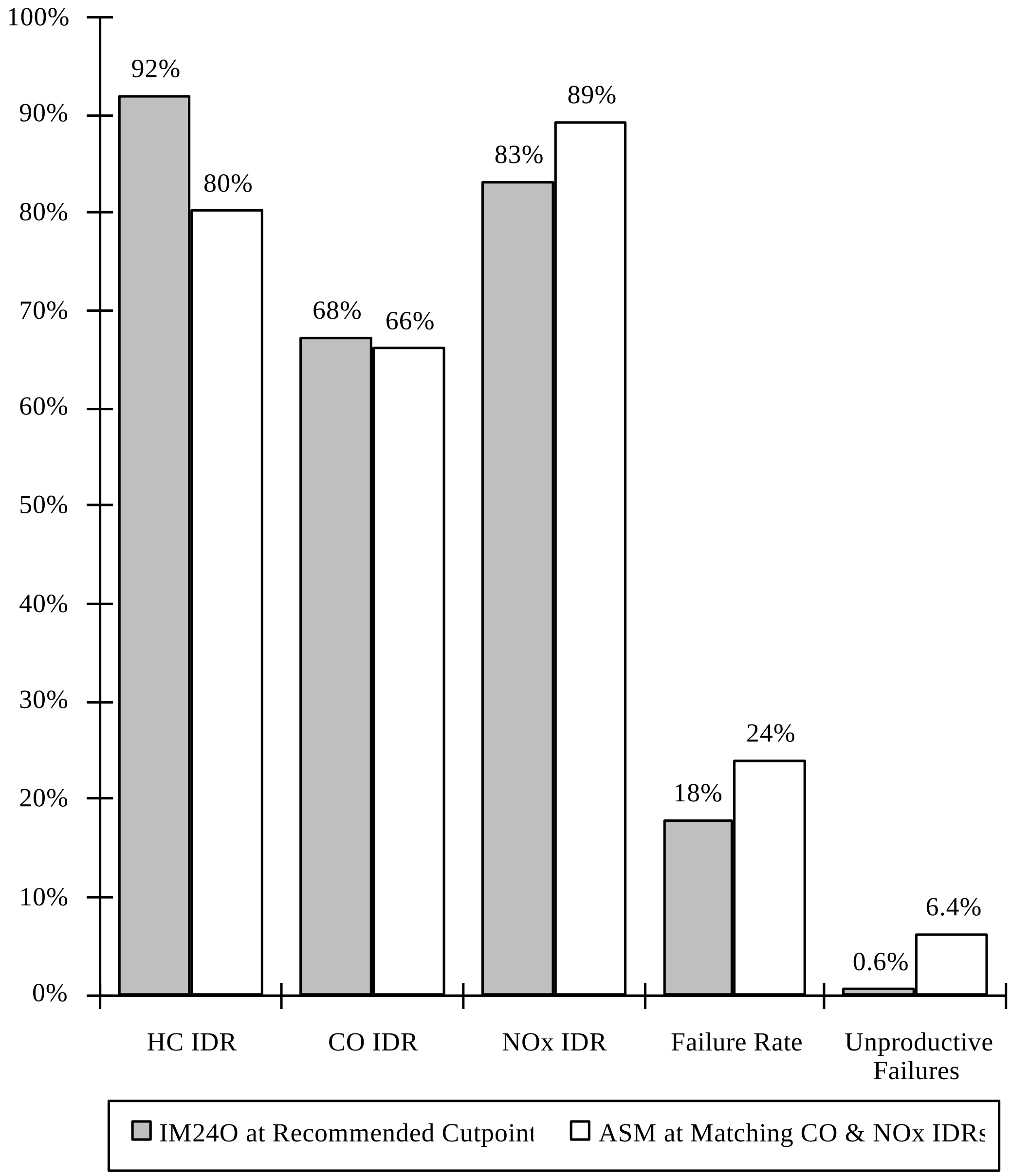
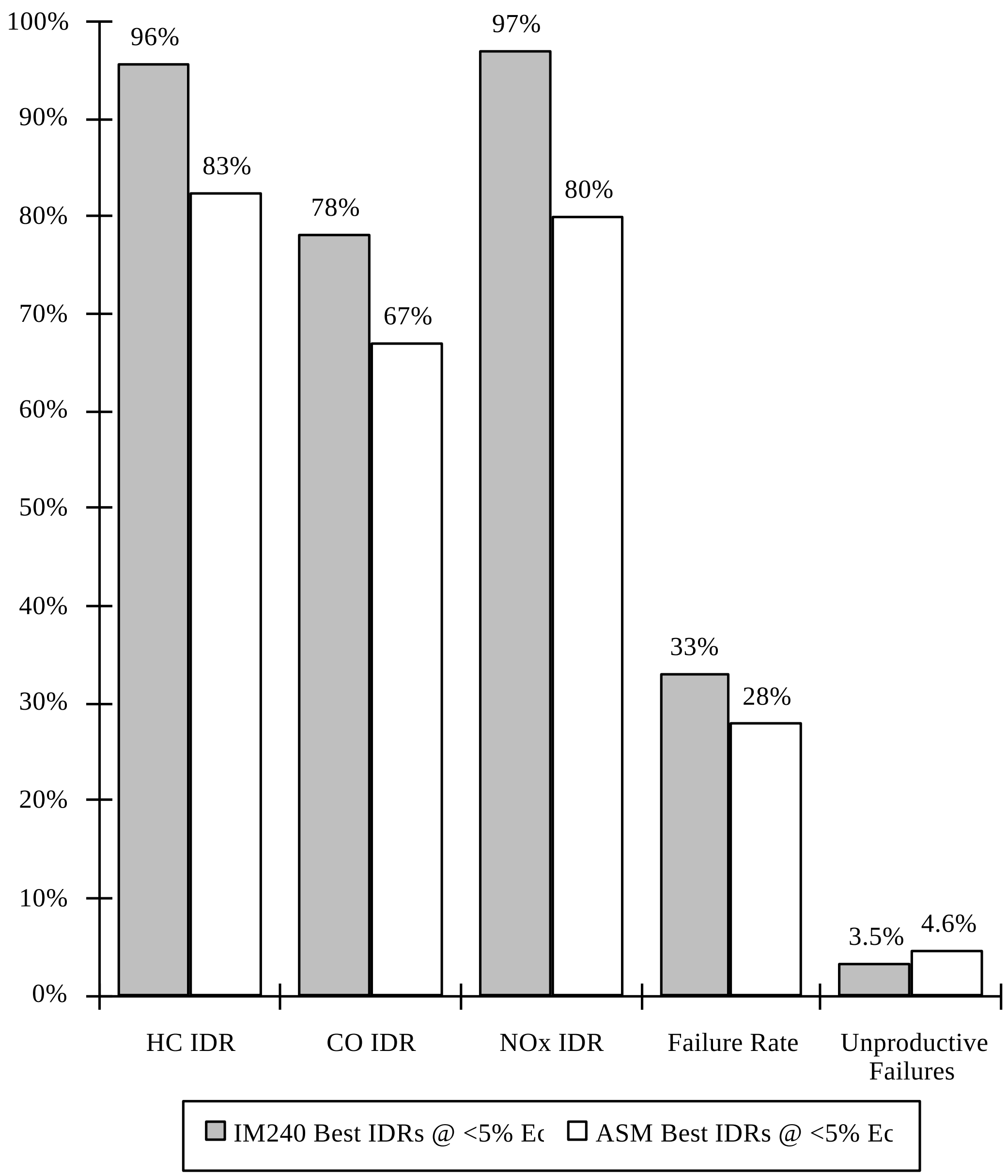


Figure 5.3.4
Comparison of ASM & IM240
Maximum IDRs @ Ec <5%



5.4 Comparison Using Scatter Plots and Regression Tables

The objective of this analysis was to check the correlation of both the IM240 and the ASM test with the FTP. The correlations are illustrated in Figures F-1 through F-9, in

Appendix F. Appendix F includes regression tables along with these scatterplots. The regressions show similar R^2 over the entire data range, but the IM240 correlates much better to the FTP for vehicles emitting closer to the FTP standards.

5.4.1 Using the Coefficient of Determination (R^2) and Standard Error of the Estimate for Objective Comparisons

R^2 represents the percentage of variability in the dependent variable (FTP result) that is explained by the independent variable (I/M test result) and is often used to compare one I/M test's effectiveness with another's, but R^2 can often be misleading. Since R^2 is often used in correlation studies, it does provide an indication of comparative test accuracy that would be of interest to readers accustomed to seeing such comparisons. More important, however, is how well these tests discriminate between malfunctioning and properly functioning vehicles at an I/M station, which is best measured using the techniques discussed in Section 5.2.

For a vehicle to fail an IM240, it must fail the two-ways-to-pass-criteria developed by EPA (see Section 5.2.2). The R^2 values presented in this section are for composite IM240 scores only and do not account for this. Two-ways-to-pass affects the quantitative correlation between IM240 and FTP significantly because the Mode-2 HC and CO values are often more representative of vehicles' actual FTP emissions. However, EPA believes it is not appropriate to mix and match composite and Mode-2 scores into one quantitative correlation analysis.

Additionally, the R^2 comparisons presented here do not account for the sample's bias toward high emitters (discussed in Section 5.2.5.8). The 106 vehicles that were recruited to the lab for FTP testing were purposely biased to include a high number of dirty vehicles. When regressing the I/M test scores versus the FTP to determine R^2 values, these high emission values disproportionately influence some regression statistics, given the typical distribution of in-use emissions data. Thus the emission values close to the FTP standards (where comparing I/M tests is most important), have less influence on the R^2 statistic than desirable for determining the actual merits of these tests. Cutpoint tables account for this sample bias by weighting each vehicles' emissions according to the population of vehicles tested at the I/M lane.

To account for these limitations the sample was divided into the following three groups:

- **All Vehicles**. This database is not very useful for comparing correlation because the cleanest and dirtiest vehicles dominate the R^2 statistic. Both tests correctly differentiate these. More pertinent are the vehicles with emissions closer to the FTP standard, where the capability of I/M tests is not masked by the very clean and very dirty vehicles. Also, vehicle 3211 is a CO outlier for both tests. It has a major effect on the regression equation and the R^2, thus masking the typical capability for both procedures.

- **Vehicle 3211 Removed** for HC, CO, NOx. This database better characterizes the correlation of both short tests with the FTP, but for the reasons discussed, it is not the most relevant for comparing the effectiveness of the tests.

- **Marginal Emitters**: Only vehicles that are not very clean or not very dirty on FTP using following criteria:

  HC $\geq$0.30 g/mi and <1.5 g/mi on the FTP
  CO $\geq$2.5 g/mi and <25.0 g/mi on the FTP
  NOx $\geq$0.5 g/mi and <2.25 g/mi on the FTP
  Also, Vehicle 3211 was excluded as an outlier.

  All vehicles with FTP emissions less than 0.30 HC, 2.5 CO, and 0.5 NOx passed the ASM and IM240 tests, for all the cutpoint sets evaluated in Section 5.3.

The standard error is an objective measurement of test variability expressed in the units (g/mi. in this case) of the variables used in the regression. Because R^2 are expressed as percents, standard errors have an advantage of being less abstract.

Table 5.4.1 provides a summary of R^2 and standard errors for Figures F-1 through F-9 in Appendix F, divided into the 3 groups just discussed. The “Marginal Emitters” group indicates that the R^2 for the IM240 are considerably higher for HC and NOx, and somewhat higher for CO. Likewise, all the standard errors are lower for the IM240, most notably for HC.

Table 5.4.1 Summary of R^2 and Standard Errors

	Data Set:	All Vehicles		Vehicle 3211 Removed		Vehicles Near Standards	
	n:	106		105		43	
	Procedure:	IM240	ASM	IM240	ASM	IM240	ASM
HC	R^2 =	82%	73%	83%	74%	63%	17%
	Std. Error =	0.62	0.76	0.61	0.75	0.19	0.28
CO	R^2 =	54%	68%	75%	80%	25%	13%
	Std. Error =	13.4	11.2	10.0	8.9	4.3	4.6
NOx	R^2 =	70%	71%	70%	71%	46%	26%
	Std. Error =	0.65	0.64	0.66	0.64	0.34	0.39

The standard errors listed in Table 5.4.1 can be used to estimate the lowest FTP value that would confidently predict a dirty vehicle. For example, the HC standard error is 0.28 g/mi for the “Marginal Emitters” group. Since 95% of the time, a vehicle’s result will be within ±2 standard errors, this suggests that the lowest ASM HC score that confidently predicts an HC-dirty vehicle (i.e., FTP HC > 0.41) is the ASM HC score that yields (using the regression equation) an FTP HC of 0.97 g/mi [0.41 + (2 * 0.28)]. In contrast, using the IM240 error of 0.19 g/mi means the lowest IM240 score that confidently predicts a HC-dirty vehicle is 0.79 g/mi, over 18% less than the score needed to confidently predict an ASM HC dirty vehicle.

5.4.2 Advantage of Using Weighted Modes

The ASM test is given a big advantage in the way the regressions are performed because each mode is weighted separately according to the IM240. On the other hand, the IM240 score is a non-weighted score. EPA developed the IM240 to contain similar driving conditions as the FTP. However, the frequency of each condition is not proportional to the FTP. By weighting different modes of the IM240 to the FTP similar to the way EPA has weighted the 4 modes of the ASM test, EPA has found the R^2 for the IM240 to improve immensely. The current score reported for the IM240 is something like weighting each mode of the ASM test 25%. This would hurt the correlation of the ASM with the FTP, because, as is shown in Section 5.5, the 50 mph mode accounts for roughly half of the composite ASM scores for each pollutant.

5.4.3 Observations of Scatterplots

The scatterplots for the first two sets of data (Figures F-1 through F-6) do not appear much different for either test, mainly because the high emitters cause the emissions close to the standards to appear as a tight pack of data. The plots for vehicles near the standard only (Figures F-7 through F-9), however, suggest the following:

HC - The IM240 identifies the dirtier cars much better. Notice on the ASM HC plot how many high emitters (FTP HC>0.82 g/mi) still score relatively low on the composite ASM score. Six vehicles pass the very tight ASM HC cutpoint of 0.3 predicted g/mi, yet have FTP emissions greater than twice the FTP standard (0.82 g/mi).

CO - Neither test appears to correlate very well over this emission range for CO. Two issues come into play that explain why this is. First, cars with loaded canisters will have high IM240 Mode-1 CO emissions at the lane, causing the short test to have a high score while the FTP at the lab is relatively low. The second scenario is cold start problems. Two vehicles in the database (Vehicles 3175 and 3227) appear to have cold start problems, with high Mode-1 FTP CO emissions, and low Bag-3 FTP CO emissions. Since the lane test is a hot start test, these vehicles will show up clean at the lane, and the cold start FTPs will be significantly dirtier.

NOx - The IM240 has a slightly tighter fit to the regression line, and more of the FTP dirty cars fall to the upper right of the scatterplot (i.e., fail the test properly).

5.4.4 Poor ASM HC Correlation

As discussed in Section 5.3, ASM HC scores do not correlate very well with FTP HC scores. This section briefly discusses theoretically why some of these vehicles had very low ASM HC emissions, yet failed the IM240 and FTP for HC emissions. Because the contractor's mechanics were not aware of the ASM scores, vehicles were not diagnosed with the objective of determining the cause of the performance differences on these I/M tests.

The first four vehicles in Table 5.4.2 were found to have ignition problems. This is logical considering that misfire, which causes high HC, is sometimes related to load. As load increases the voltage required to jump the spark plug gap also increases. Some portions of the IM240 load the vehicle more heavily than any of the ASM modes, so a marginal ignition system that only causes misfire during the higher IM240 loads will not be identified by ASM HC.

Vehicles 3180 and 3264 were found to have bad O_2 sensors and other malfunctions. Slow responding O2 sensors are more likely to be identified during a transient test, because changing throttle position tends to cause air/fuel ratio excursions that will cause high emissions unless the fuel induction system rapidly compensates to maintain the optimum air/fuel ratio. So slow responding O2 sensor might explain the high HC on the IM240 and low HC on the ASM.

The disconnected vacuum lines on vehicle 3201 could have caused lean-misfire during accelerations on the IM240 that would not be apparent on the steady-state modes of the ASM.

These explanations can not be proven with the existing data, but they should indicate that a steady-state test suffers from known disadvantages in identifying vehicles with these types of malfunctions.

Table 5.4.2 Vehicles with Poor ASM HC Correlation

VEH	ASM HC	FTP HC	IM240 HC	Problem Found
3259	0.23	1.94	1.50	Ignition Module
3257	0.25	1.26	1.92	Plug Wires, Plugs Transducer, Ignition Coil Transistor
3155	0.34	3.25	2.77	Incorrect Plugs, Torn wire boot
3210	0.35	1.40	1.04	O2 Sensor, Spark Plugs, Fuel Hose, Catalyst
3180	0.15	0.96	1.33	O2 Sensor and Injectors
3264	0.49	1.36	2.16	O2 Sensor, Vacuum Switching Valve
3254	0.29	1.87	2.26	ECU Intermittent, Catalyst
3201	0.17	0.94	1.15	Vacuum Lines Disconnected
3165	0.39	1.96	1.59	Dirty Injectors

5.5 Derivation of ASM Coefficients and Mode Contribution Variations From Sample to Sample

This section discusses why the ASM coefficients that EPA based its analyses on were developed using the IM240 as the dependent variable rather than the FTP. BAR/Sierra and ARCO used the FTP to develop ASM Coefficients.

Also discussed are the rather large variations in the ASM coefficients with different samples, and the variation in the contribution of each ASM mode to the final ASM score (expressed as percent contribution).

5.5.1 ASM Versus IM240 As The Dependent Variable For Determining ASM Coefficients

EPA faced a dilemma in determining the best method for developing the ASM equation coefficients. No ASM advocate has recommended specific coefficients, on which, EPA should accept or reject the ASM approach. So two options were to: 1) perform the multiple regressions on all the lab recruited vehicles for ASM versus FTP. Or, 2) perform the multiple regressions for ASM versus IM240 on a subset of the lane sample, excluding all lab recruited cars.

Obviously, the ideal method is to regress the ASMs versus FTPs (i.e., option 1), but this raises a problem. To evaluate how well the ASM identifies FTP failing vehicles, the coefficients must be applied to the lab recruited vehicles to calculate simulated grams/mile scores. However, good statistical practice mandates applying the coefficients to a different sample than those from which they were developed.

This interlinking method, wherein the coefficients are applied to the same vehicles from which they were developed, would minimize the effects of the test's variability. This improper interlinking is illustrated using results from Vehicle 3211. This vehicle's lane-IM240 CO score was 93 g/mi and its ASM CO score was 65 g/mi using the coefficients from the 608 vehicle sample listed in Table 5.5.1 (The relevance of the other samples in this table will be discussed later). Its FTP CO score was only 10.8 g/mi.

Table 5.5.1
CO Coefficients Developed from Different Samples

Mode	CO Sample 1	CO Sample 2	CO All 608	CO vs FTP
Constant	2.814	2.836	2.936	5.533
5015	0.035	0.116	0.040	**-0.047**
2525	0.072	**-0.058**	0.043	0.565
50 MPH	0.425	0.391	0.356	0.050
Idle	0.891	2.014	1.350	1.968
Adjusted R^2	34.2%	58.4%	50.1%	80.6%

The scatter plots below show that using the IM240-developed coefficients cause this vehicle to be easily identified as an outlier. In marked contrast, using the FTP-developed coefficients make it look like this vehicle's ASM score highly correlates to its FTP score. The ASM mode scores are weighted differently, so the high scoring mode(s) are de-emphasized. But these same-sample FTP-based ASM coefficients are obviously peculiar to this sample, and highly dependent on it containing this one particular car. (See Tables 5.5.1 and 5.5.6.)

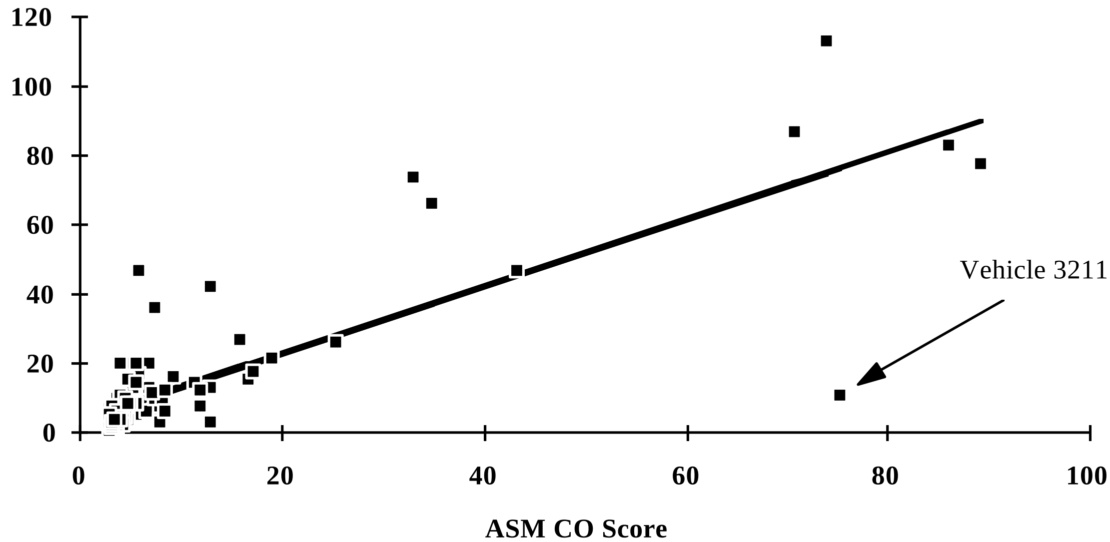
Still not answered is which ASM coefficients better indicate whether the vehicle is malfunctioning or not. Some could argue that this vehicle should not be an outlier. Instead, the IM240-developed coefficients inappropriately make it appear as an outlier. Attempting to resolve this, the raw ASM concentration measurements were checked. This vehicle's 50 mph mode CO concentration was 4.96%, which is higher than 97% of vehicles recruited to the lab (103 of the 106 vehicles).

Using the same-sample, FTP-based ASM coefficients prevents this vehicle from being an outlier because they adjust themselves to minimize the effect of the 50 mph mode score from all cars. Additionally, the very high concentration measurement (4.96%) proves that the vehicle had a malfunction causing very high emissions that had been inappropriately minimized. (This was also verified during the mechanic's inspection which found a defective O2 sensor and that an ECM PROM update was required.) This evidence strongly supports EPA's properly using the preconditioned IM240s as the dependent variable for developing ASM coefficients to compare the ASM and IM240 correlations with the FTP.

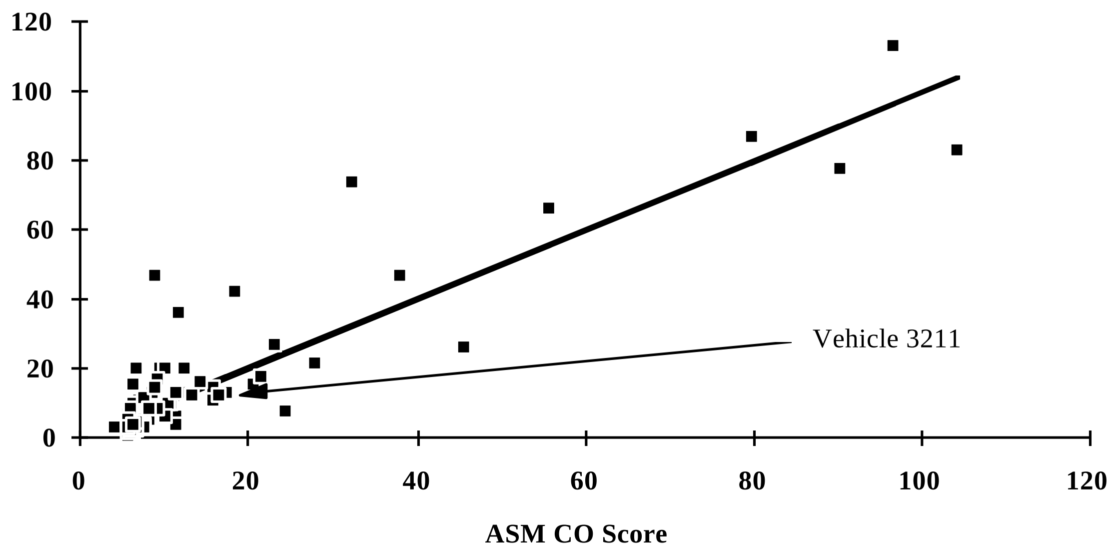
This evidence also casts doubt on conclusions developed from test programs that used interlinked coefficients. Interlinking makes the correlation between the ASM, or any other test, and the FTP significantly better than could be expected in an official I/M program. Since I/M programs will apply ASM coefficients to vehicles that were never FTP tested, the opportunity for interlinking will not exist, so ASM performance should not be evaluated using interlinked coefficients.

Another reason for EPA's not using FTP-based coefficients is because some are negative, which means that as ASM5015 emissions increase, FTP emissions decrease. This is counter-intuitive.

ASM Coefficients Developed
from
608 Lane ASM vs Pre-Conditioned IM240s



ASM Coefficients Developed
from
106 Lane ASM vs Lab FTP

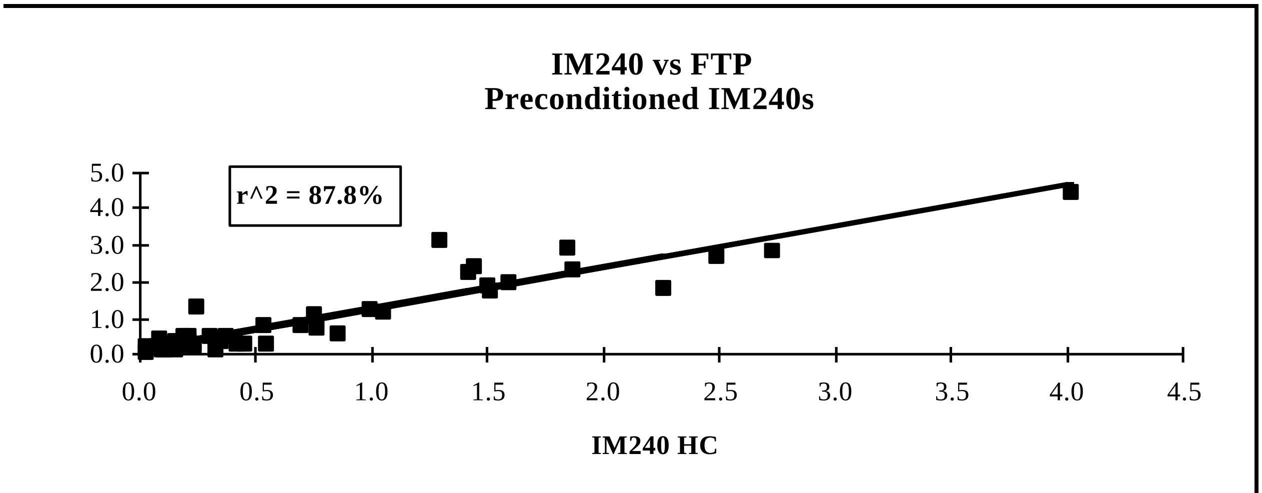


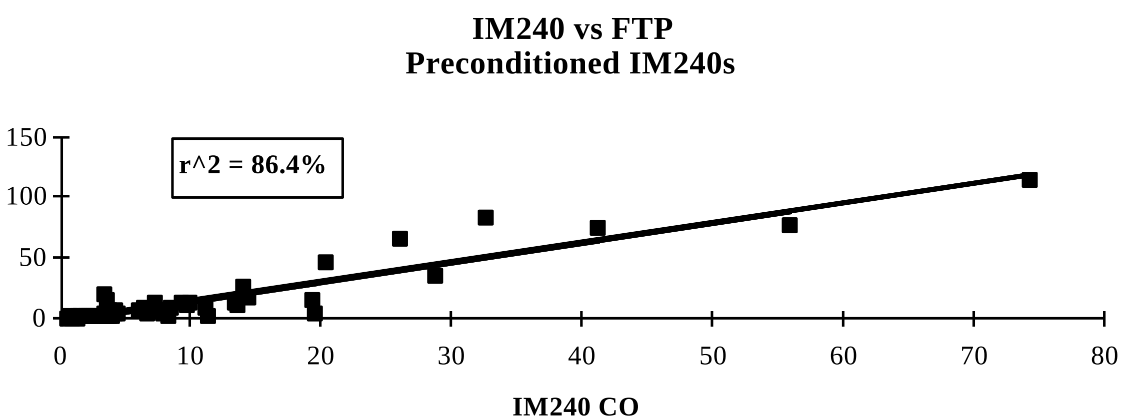
EPA decided that the best method, using the Arizona data, was to regress the four steady-state modes (three for NOx) against lane-only, preconditioned IM240s. There were three major factors leading to this decision. First, this allowed applying the coefficients to a different subset of data (the lab recruited vehicles). Second, the sample size was considerably larger (608 vs. 106 tests). EPA's FTP sample was too small to divide and use half to determine coefficients and the other half to evaluate ASM effectiveness, which is supported by the negative coefficient yielded for the ASM5015 listed in Table 5.5.1. Third, only preconditioned IM240s were used because they correlate better with the FTP than non-preconditioned IM240s. The only significant compromises in using IM240s instead of FTPs is that the composite ASM score does not include a cold start excess (which would be independent of warmed-up ASM mode concentrations anyway) and that the mix of speeds and loads in IM240 is not exactly like that in the full FTP driving cycle (a hardship borne by the IM240 in its own correlation to the FTP).

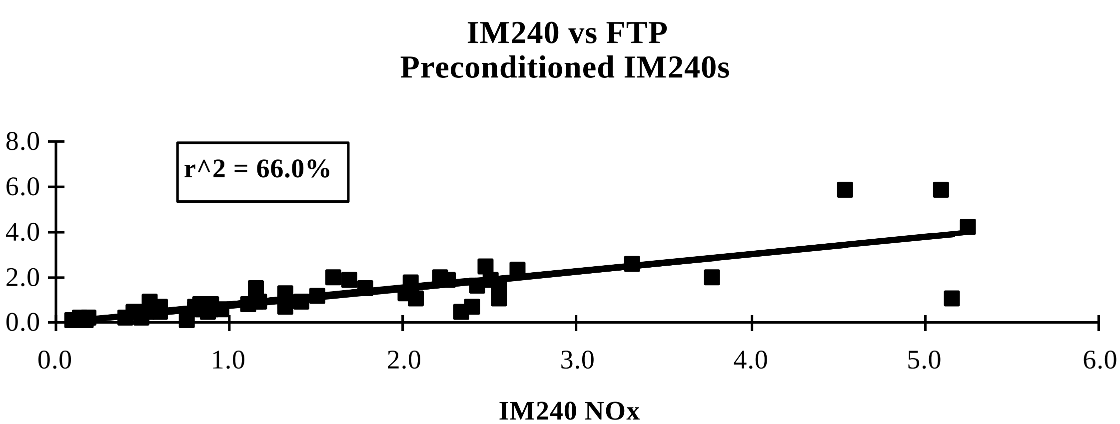
Figure 5.5.1 illustrates that preconditioned IM240s strongly correlate with the FTP. These data are from the 106 lab recruited vehicles, but are restricted to IM240s that were performed following the ASM at the lane, making them preconditioned IM240s.

NOx has the worst correlation because of a few outliers at the high end, but this is not a concern for the ASM since the NOx coefficients are relatively stable, which is discussed in the next section.

Figure 5.5.1 High Correlation of Preconditioned Lane-IM240s with FTPs







5.5.2 Variability of ASM Coefficients

The objective of the following analysis was to investigate the stability of the coefficients used to calculate composite ASM simulated grams/mile scores. The database was divided into four samples for comparison.

Sample 1 was developed by using a random number generator to select 304 vehicles from the lane-only fleet of 608. The remaining 304 vehicles became Sample 2. Sample 3 was all 608 vehicles, and the fourth sample was the 106 laboratory vehicles. The ASM coefficients for the first three samples were developed using the IM240 as the dependent variable and the FTP sample used the FTP for the dependent variable. The resulting coefficients are listed in the following tables. (Table 5.5.3 is a duplicate of Table 5.5.1.).

Table 5.5.2

HC Coefficients Developed from Different Samples

Mode	HC Sample 1	HC Sample 2	HC All 608	HC vs FTP
Constant	0.080	0.073	0.083	0.291
5015	0.045	0.008	0.025	**-0.261**
2525	0.047	0.059	0.059	0.507
50 MPH	0.147	0.123	0.136	0.238
Idle	0.084	0.585	0.124	0.154
Adjusted R^2	21.7%	38.9%	29.0%	79.4%

Table 5.5.3

CO Coefficients Developed from Different Samples

Mode	CO Sample 1	CO Sample 2	CO All 608	CO vs FTP
Constant	2.814	2.836	2.936	5.533
5015	0.035	0.116	0.040	**-0.047**
2525	0.072	**-0.058**	0.043	0.565
50 MPH	0.425	0.391	0.356	0.050
Idle	0.891	2.014	1.350	1.968
Adjusted R^2	34.2%	58.4%	50.1%	80.6%

Table 5.5.4
NOx Coefficients Developed from Different Samples

Mode	NOX Sample 1	NOX Sample 2	NOX All 608	NOX vs FTP
Constant	0.230	0.279	0.258	0.190
5015	0.088	0.045	0.061	0.148
2525	0.206	0.212	0.219	0.093
50 MPH	0.386	0.333	0.352	0.291
Adjusted R^2	60.2%	57.9%	59.1%	71.1%

The negative coefficients are highlighted in bold. One could infer from the negative coefficients that increasing the emissions during that mode of the ASM would lower the composite score.

These coefficients were used with the ASM data, from each of the 106 lab-recruited vehicles, to calculate the emissions for each mode and the percent of the total emissions that each mode contributed. These mode contributions give a better indication of each modes importance in the final ASM score, than the coefficients, which are more difficult to interpret. The results are listed in the following tables:

Table 5.5.5
Average Contribution of Total HC Emissions by Mode

Mode	HC Sample 1	HC Sample 2	HC All 608	HC vs FTP
Constant	17%	17%	19%	11%
5015	20%	4%	12%	-75%
2525	17%	22%	22%	116%
50 MPH	43%	39%	43%	45%
Idle	2%	18%	4%	3%

Table 5.5.6
Average Contribution of Total CO Emissions by Mode

Mode	CO Sample 1	CO Sample 2	CO All 608	CO vs FTP
Constant	26%	27%	29%	28%
5015	4%	12%	4%	-5%
2525	7%	-6%	4%	55%
50 MPH	57%	53%	51%	7%
Idle	6%	15%	11%	15%

Table 5.5.7
Average Contribution of Total NOx Emissions by Mode

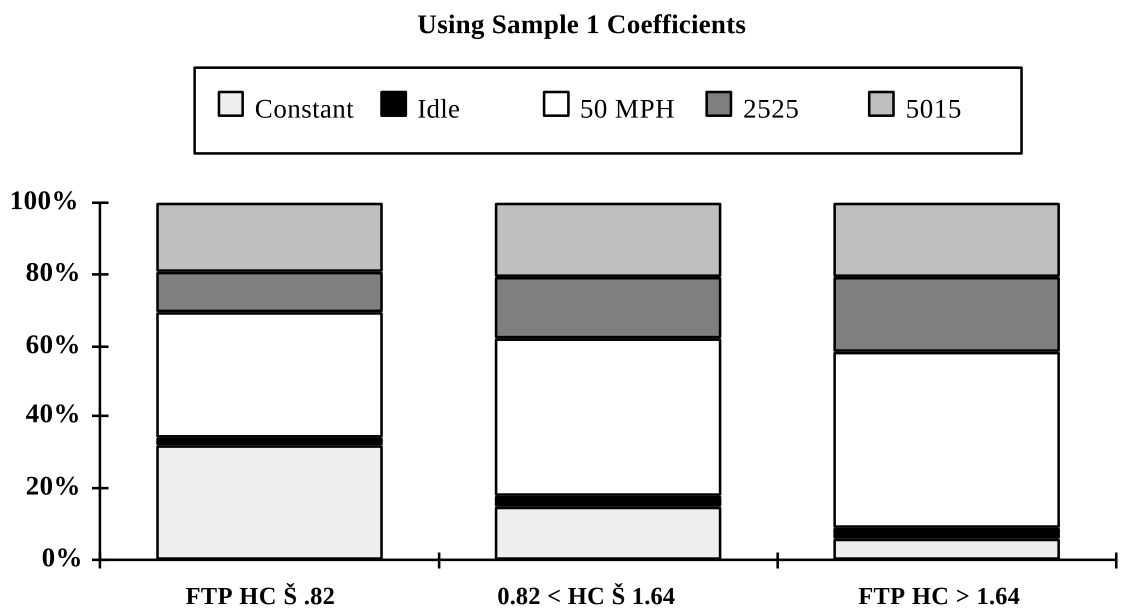
Mode	NOX Sample 1	NOX Sample 2	NOX All 608	NOX vs FTP
Constant	15%	20%	17%	20%
5015	11%	6%	8%	22%
2525	24%	27%	27%	13%
50 MPH	50%	47%	48%	45%

The HC coefficients in particular are very volatile, and that the negative FTP-developed coefficients are counter-intuitive. When applying the coefficients from Sample 1, the idle mode, on average, only contributes 2% to the total score. This contribution jumps to 18% when the coefficients from Sample 2 are applied. Similarly the ASM5015 contribution drops from 20% to 4%. These examples indicate that the largest sample (608 vehicles) with preconditioned IM240s was the best sample available for developing ASM coefficients.

5.5.3 Significance of Mode Contributions

The ASM mode contributions also vary as the composite ASM score moves from low values (for which the constant term will be the primary contributor to the composite score) to relatively high values (for which the constant term will be a relatively small contributor to the composite emission). This is illustrated in Figures 5.5.2 to 5.5.4. For CO, the ASM5015 and ASM2525 are combined, because of the negative contributions of 2525 and the small contribution of the ASM5015 in relation to the 50 mph mode.

Figure 5.5.2
Mode Contributions for HC



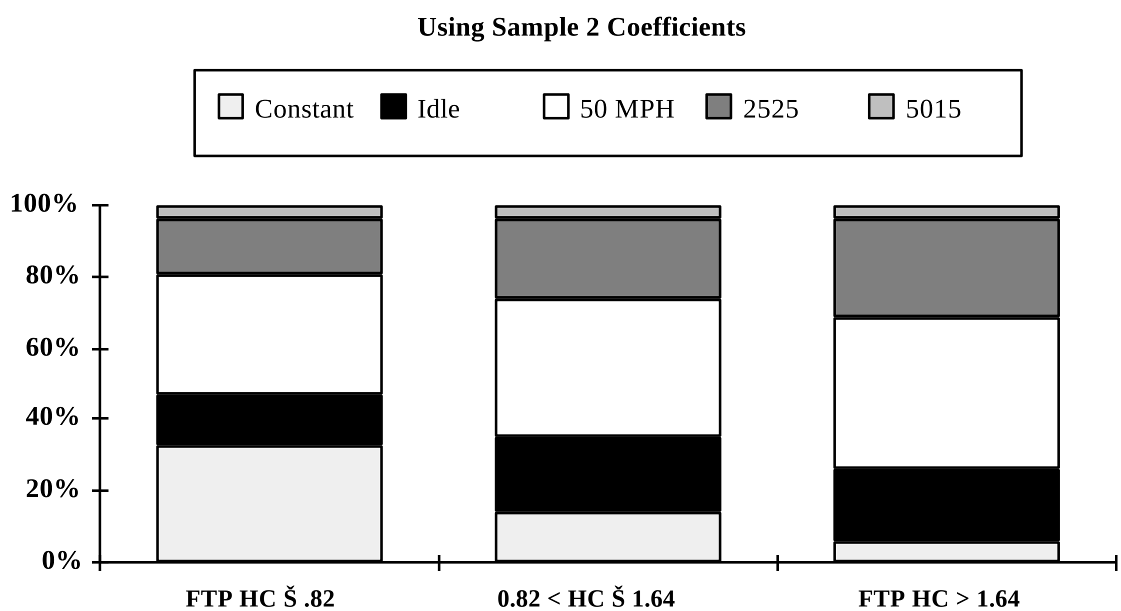
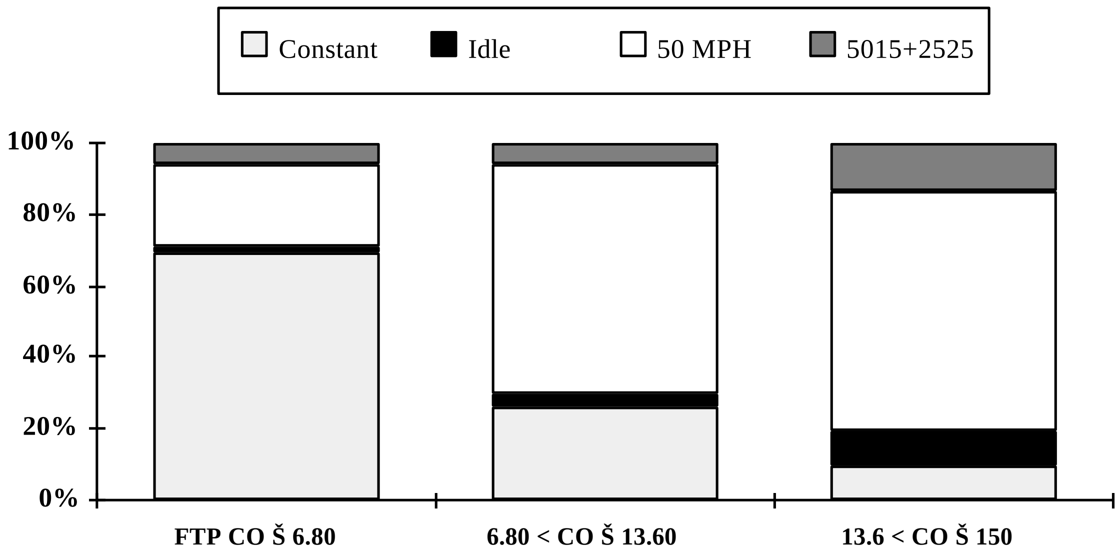


Figure 5.5.3
Mode Contributions for CO

Using Sample 1 Coefficients



Using Sample 2 Coefficients

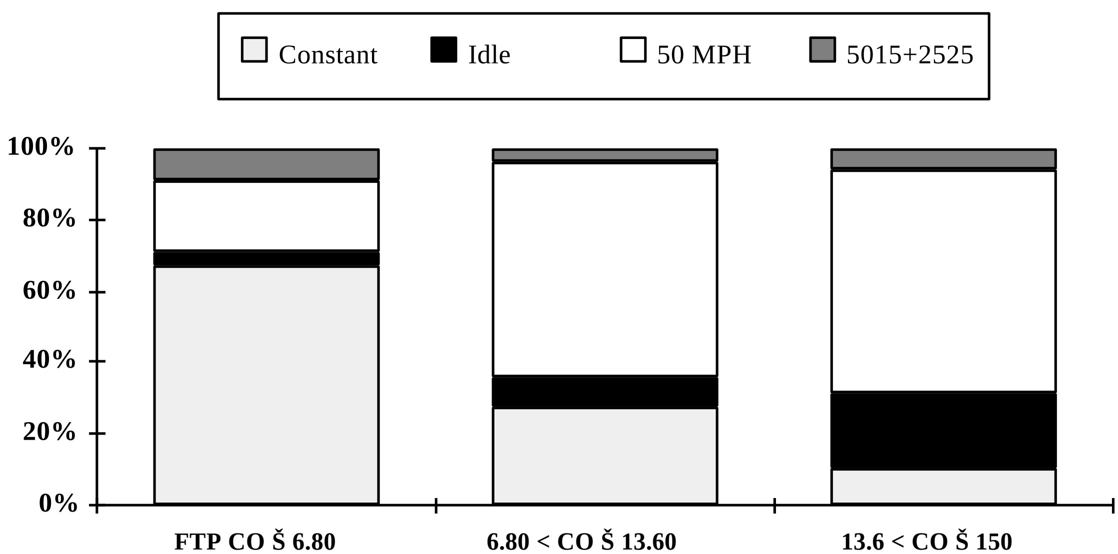
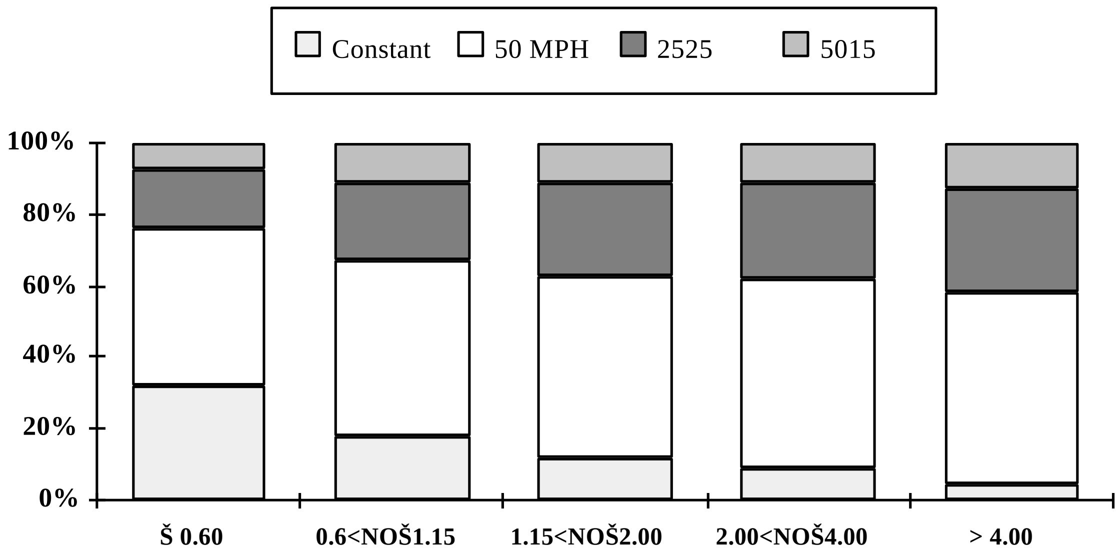
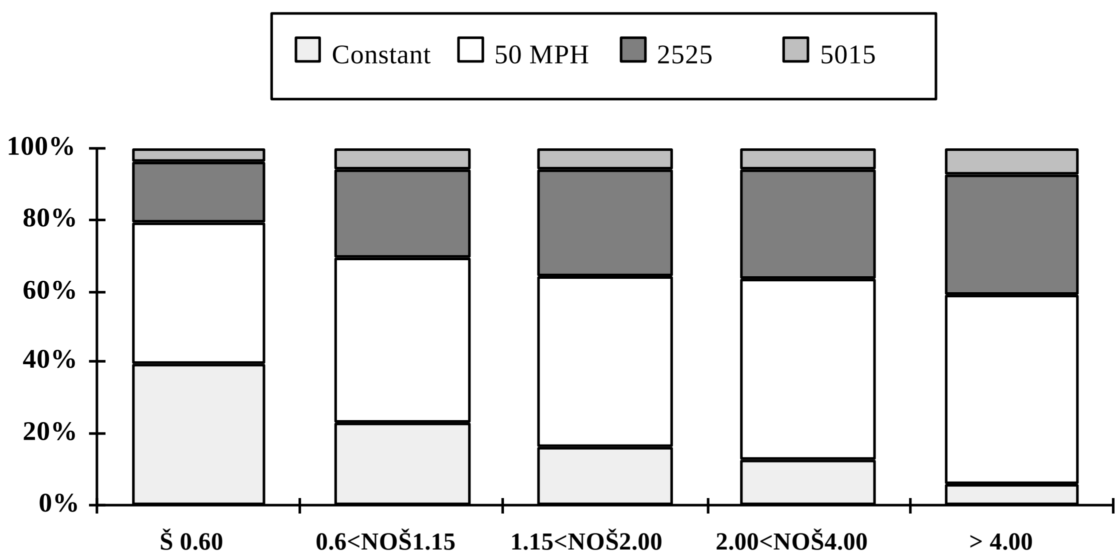


Figure 5.5.4
Mode Contributions for NOx

Using Sample 1 Coefficients



Using Sample 2 Coefficients



The fact that the 50 mph mode contributes so much to the composite score for each pollutant is also reason for concern. This opens the opportunity for mechanics to adjust vehicles to lower emissions for just one mode (namely the 50 mph), which will be further discussed in Sections 5.6.3 and 5.6.4.

5.5.4 Conclusions on ASM Mode Contributions

While not a mode that was recommended by the ASM developers, the 50 mph mode at road load horsepower appears to be more important for identifying dirty vehicles than the lower speed, acceleration simulation modes (ASM5015 and ASM2525). Surprising was the small contribution of the ASM5015 (mode 1) for identifying dirty vehicles considering that BAR/Sierra and ARCO both found this mode to be the most effective. This suggests that the first mode in a four mode sequence serves mainly to precondition vehicles for the following modes. Randomizing the order of the modes may be useful in determining the best sequence.

For the cutpoint analysis in Section 5.3 and the regression analysis in Section 5.4, the ASM scores used were those calculated from the coefficients developed from the 608 ASM versus preconditioned lane-IM240s. However, the variability of the HC coefficients between the two random subsets of 304 tests suggest that a different sample of 608 tests might produce substantially different equation coefficients. The resulting change in HC (and in some cases CO and NOx) ASM scores would produce different failure rates, IDRs, and Ec rates in the cutpoint tables, and different R^2 values in the regressions of ASM versus FTP. So the volatile coefficients may vary from sample to sample, or worse yet region to region, resulting in disparate I/M programs which would be hard to evaluate on a consistent basis.

5.6 Repair Analyses

5.6.1 Contractor Repairs

The objective of this analysis was to investigate the performance of both the IM240 and the ASM tests as predictors of changes (i.e., decreases or increases) in FTP emissions following contractor-performed, IM240-targeted repairs.

Of the 106 vehicles used in the cutpoint analysis (Table 4.2.2), 56 exceeded the lane-IM240 0.80/15.0/2.0 + 0.50/12.0 cutpoint and were repaired by the contractor. Of these, 52 received each of the three following tests both prior to repairs (i.e., as-received) and following repairs:

- a Lane-IM240,
- a Lane-ASM, and
- an FTP.

These 52 were used in this analysis and are included with the data listed in Appendix B. The resulting database of those 52 fuel-injected vehicles has the following distribution:

	Order of Lane Testing	
Fuel Metering	**ASM Prior to IM240**	**IM240 Prior to ASM**
PFI	14	16
TBI	11	11

The contractor was instructed to perform the minimum repairs necessary in order that each vehicle’s IM240 emissions after repair (as tested at the contractor’s laboratory) meet the following criteria:

- composite IM240 HC ^{2} 0.80 g/mi,
- composite IM240 CO ^{2} 15.00 g/mi, and
- composite IM240 NO_X ^{2} 2.0 g/mi.

The contractor was allowed multiple repair attempts if the first set of repairs did not reduce the IM240 emission levels enough. The repairs were limited to $1,000 per car. And, the contractor was instructed that “the mechanic should only be aware of the IM240 scores for the IM240-targeted repairs.” Because ASM cutpoints, that could distinguish malfunctioning vehicles from properly functioning vehicles, were not yet developed, only IM240-targeted repairs were performed.

These IM240 emission repair criteria were met at the contractor’s laboratory for all cars prior to the second and final FTP, with the highest after-repair laboratory IM240 composite HC emission score of 0.56, CO of 10.82, and NOx of 1.93 (g/mi). The effects of those IM240-targeted repairs on FTP emissions are illustrated in the following table:

Table 5.6.1.1

FTP Emissions Prior to and Following IM240-Targeted Repairs

FTP Emissions		Mean	Range of Emissions Minimum	Range of Emissions Maximum
HC	As-Received	1.458	0.16	13.07
	After Repair	0.326	0.10	0.75
CO	As-Received	19.707	0.28	113.40
	After Repair	3.331	0.63	8.82
NOx	As-Received	1.649	0.20	7.56
	After Repair	0.739	0.05	1.81

The resulting FTP emissions after the IM240-targeted repairs were essentially independent of the as-received FTP emissions. (That is, the R-squares associated with before and after HC, CO, and NO_X were only 0.1%, 1.2%, and 1.0%, respectively.)

The data from these repaired vehicles can give insight into the question of whether the IM240 test and cutpoints cause repairs to be made which also reduce FTP emissions. In other words, does the IM240 and the FTP correlate well on a single vehicle? This correlation is to be expected based on the realistic nature of the IM240 driving cycle, and the good correlation found in samples of vehicles not repaired.

For each of those 52 vehicles (all 1983 and newer fuel-injected cars), the change in each pollutant (HC, CO, and NO_X), following contractor repairs, was calculated for each of those three test cycles. Regressing the reductions in the lane emissions against the reductions in FTP emissions produced Tables 5.6.1.2 and 5.6.1.3. The six graphs (Figures 5.6.1.1 through 5.6.1.3) that follow those regression tables illustrate the results of this analysis.

Table 5.6.1.2

Regression of Changes in Lane-IM240 Emissions Following Contractor Repairs Versus Corresponding Changes in FTP Emissions

Dependent variable is:		**Æ(FTP HC)**		
R^2 = 81.9%				
s = 0.8320 with 52 - 2 = 50 degrees of freedom				
Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	156.693	1	157	226
Residual	34.611	50	0.69222	
Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	
Constant	-0.365173	0.1524	-2.4	
Æ(IM240 HC)	1.4106	0.0938	15	

Dependent variable is:		**Æ(FTP CO)**		
R^2 = 47.5%				
s = 18.50 with 52 - 2 = 50 degrees of freedom				
Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	15469.4	1	15469	45.2
Residual	17110.1	50	342.203	
Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	
Constant	4.64057	3.103	1.5	
Æ(IM240 CO)	0.846373	0.1259	6.72	

Dependent variable is:		**Æ(FTP NOx)**		
R^2 = 64.5%				
s = 0.8846 with 52 - 2 = 50 degrees of freedom				
Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	71.1008	1	71.1	90.9
Residual	39.1265	50	0.78253	
Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**	
Constant	-0.275563	0.1747	-1.58	
Æ(IM240 NOx)	0.738523	0.0775	9.53	

Table 5.6.1.3

Regression of Changes in Lane-ASM Emissions Following Contractor Repairs Versus Corresponding Changes in FTP Emissions

Dependent variable is: **Æ(FTP HC)**

R^2 = 71.7%

s = 1.040 with 52 - 2 = 50 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	137.187	1	137	127
Residual	54.1169	50	1.08234	

Variable	Coefficient	s.e. of Coeff	t-ratio
Constant	0.270944	0.1633	1.66
Æ(ASM HC)	2.18967	0.1945	11.3

Dependent variable is: **Æ(FTP CO)**

R^2 = 79.5%

s = 11.55 with 52 - 2 = 50 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	25906.3	1	25906	194
Residual	6673.29	50	133.466	

Variable	Coefficient	s.e. of Coeff	t-ratio
Constant	5.71775	1.775	3.22
Æ(ASM CO)	1.08685	0.078	13.9

Dependent variable is: **Æ(FTP NOx)**

R^2 = 70.8%

s = 0.8016 with 52 - 2 = 50 degrees of freedom

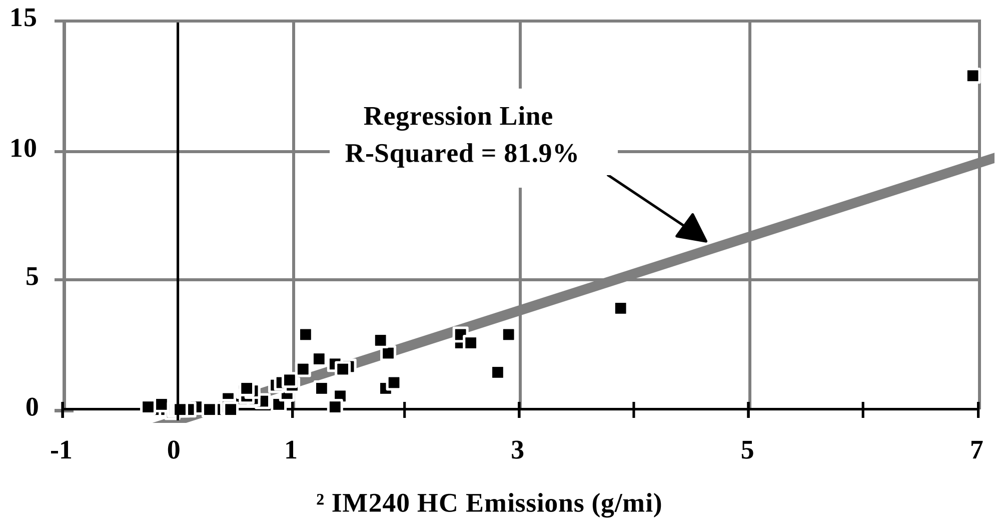
Source	Sum of Squares	df	Mean Square	F-ratio
Regression	78.0956	1	78.1	122
Residual	32.1317	50	0.642635	

Variable	Coefficient	s.e. of Coeff	t-ratio
Constant	-0.013624	0.1392	-0.098
Æ(ASM NOx)	0.829714	0.0753	11

Figure 5.6.1.1

Decreases in HC Emissions Following Repairs

^{2}FTP vs ^{2}IM240 HC



^{2}FTP vs ^{2}ASM HC

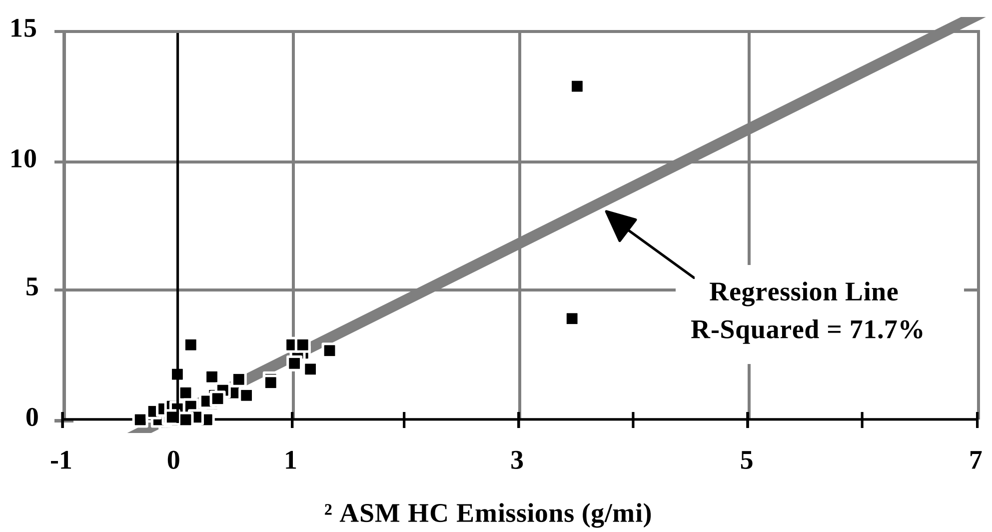
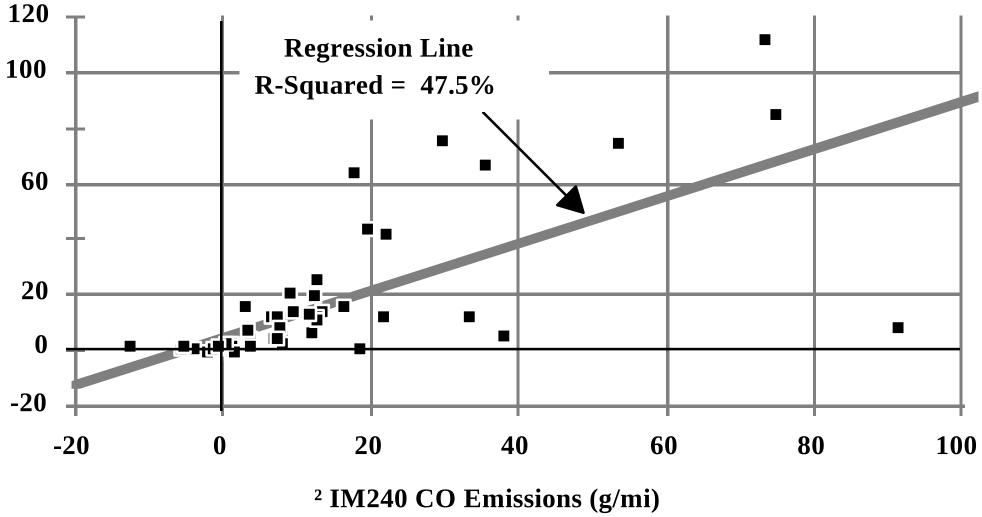


Figure 5.6.1.2

Decreases in CO Emissions Following Repairs

²FTP vs ²IM240 CO



²FTP vs ²ASM CO

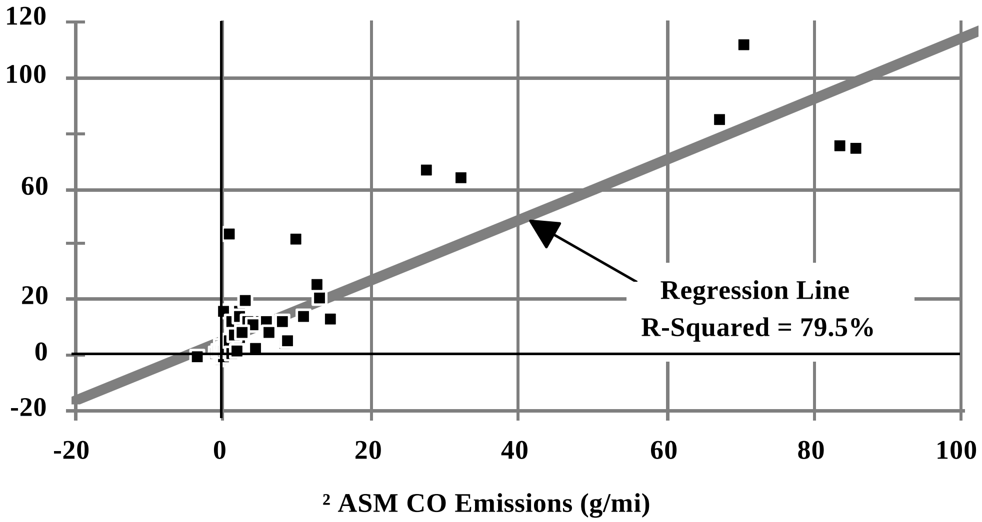
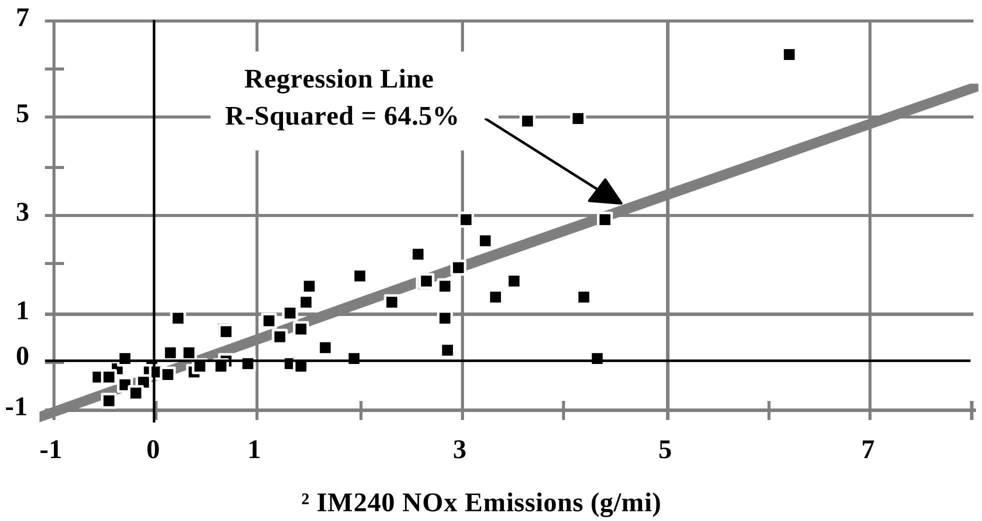


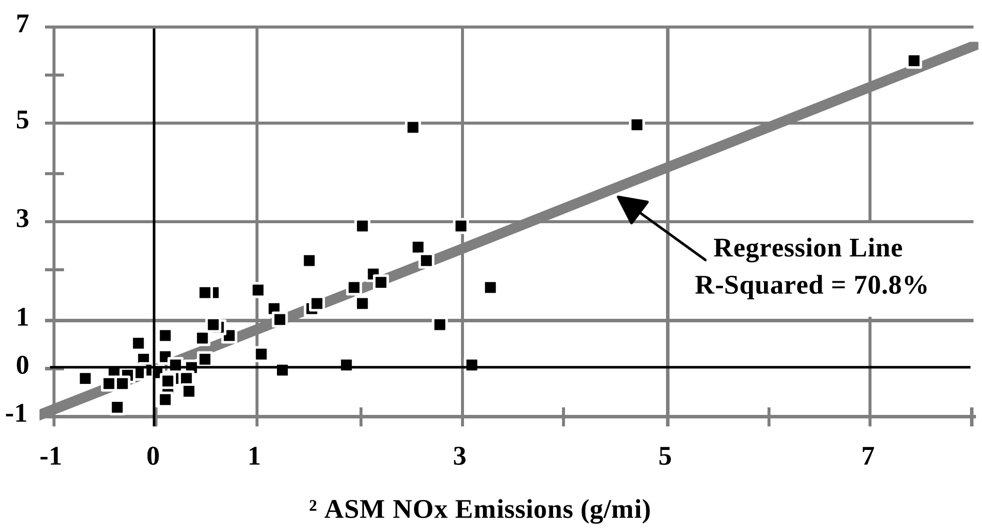
Figure 5.6.1.3

Decreases in NOx Emissions Following Repairs

²FTP vs ²IM240 NOx



²FTP vs ²ASM NOx



Comparing the two graphs that examine the changes in HC emissions (Figure 5.6.1.1), it is apparent that one vehicle (vehicle number 3190) exhibited a reduction in FTP HC emissions substantially greater than any of the other 51 vehicles (12.88 g/mi HC reduction compared to only 3.86 for the next larger FTP HC reduction). Since it is possible that one such vehicle could substantially affect the regression analysis, a second set of regressions were performed on the remaining 51 cars (i.e., with vehicle number 3190 deleted) to determine the effect. The effects on the slopes of the regression lines are given in Tables 5.6.1.4 and 5.6.1.5.

Table 5.6.1.4
Effect on IM240 Regression Line
For HC Emissions
Of Deleting Vehicle 3190

	Based on All 52 Vehicles	Based on 51 Vehicles
Constant	-0.365173	0.018227
Coefficient	1.4106	0.93431
R^2	81.9%	74.7%

Table 5.6.1.5
Effect on ASM Regression Line
For HC Emissions
Of Deleting Vehicle 3190

	Based on All 52 Vehicles	Based on 51 Vehicles
Constant	0.270944	0.452113
Coefficient	2.18967	1.35391
R^2	71.7%	67.8%

From Tables 5.6.1.4 and 5.6.1.5, we see that deleting that potential HC outlier (vehicle number 3190) has a similar effect on each regression line. The slope of the IM240 regression line decreases 11.6 degrees, and the slope of the ASM regression line decreases 11.9 degrees. Since deleting the change in HC emissions of vehicle 3190 from the sample has the same effect on both regression lines, it would be advisable to use the equations based on 51 cars to estimate changes in FTP HC emissions based on IM240 and/or ASM HC changes, for IM240 and/or ASM HC changes between -1.0 and +4.0 g/mi.

Comparing the two graphs that examine the changes in CO emissions (Figure 5.6.1.2), it appears, at first glance, that the composite IM240 tends to over predict the repair benefit to CO emissions for some vehicles with relatively small FTP CO repair benefits. However, the actual situation is that several relatively cleaner vehicles (though still exceeding FTP standards) had unusually high IM240 results on their first test. IM240 CO was a lot lower after repair, but the FTP emissions had comparatively little room to improve. The five vehicles in Figure 5.6.1.2 that exhibit this problem (vehicles numbered: 3157, 3175, 3211, 3213, and 3214) all have as-received composite FTP CO less than 15 g/mi. For two of those five, most of the high composite IM240 emissions resulted from the first mode (i.e., the first 93 seconds) of the IM240. For this reason, EPA has recommended that vehicles which fail the composite HC or CO cutpoint be given a second chance to pass by examining the Mode-2 emissions (see "Two-ways-to-pass" in Section 5.3). A similar situation cannot happen for the ASMs as analyzed in this report because the weighting factors, in effect, cause the CO scores on the first mode (5015) to be ignored. One vehicle that deserves special note is vehicle number 3211. That vehicle exhibited the largest IM240 CO reduction (91.70 g/mi), but an FTP CO reduction of only 8.00 g/mi. This high lane-IM240 CO reduction resulted from a high initial (i.e., as-received) lane test score of 93.07 g/mi, but an initial FTP CO score of 10.79. (However, the lane score was confirmed by an indolene-fueled lab-IM240 following the FTP which had a CO result of 52.48 g/mi.) The ASM tests on this vehicle did not exhibit a large CO reduction following repairs because both the initial ASM and the ASM following repairs exhibited very high CO emissions (more than 5%) during the 50 mph cruise mode. (Thus, the ASM did not over estimate the CO repair benefit on vehicle 3211 because the ASM over estimated both the initial FTP CO emissions, as well as, the FTP CO emissions following repair.) In spite of the few over predictions of emission benefits from repairs, it should be noted (as illustrated in Table 5.6.1.1) that following the IM240-targeted repairs, no vehicle was left with high unrepaired FTP emissions.

Most of the vehicles, which exhibited very little if any HC or CO improvement following the IM240-targeted repairs, had been recruited for repairs because they exhibited, on the lane-IM240 test, low HC and CO, but high NO_X. Therefore, no significant improvement in either FTP HC or CO was to be expected.

Comparing the two graphs that examine the changes in NO_X emissions (Figure 5.6.1.3), it is apparent that one vehicle (vehicle number 3202) exhibited a reduction in FTP NO_X emissions greater than any of the other 51 vehicles (6.31 g/mi NO_X reduction compared to 4.98 for the next larger FTP NO_X reduction). Since it is possible that one such vehicle could substantially affect the regression analysis, a second set of regressions were performed on the remaining 51 cars (i.e., with vehicle number 3202 deleted) to determine the effect. The effects on the slopes of the regression lines are given in Tables 5.6.1.6 and 5.6.1.7. From Tables 5.6.1.6 and 5.6.1.7, we see that deleting that potential NO_X outlier (vehicle number 3202) has virtually no effect on either regression line. The slope of the IM240 regression line decreases only 3.3 degrees, and the slope of the ASM regression line decreases less than half a degree.

Table 5.6.1.6
Effect on IM240 Regression Line
For NO_X Emissions
Of Deleting Vehicle 3202

	Based on All 52 Vehicles	Based on 51 Vehicles
Constant	-0.275563	-0.183932
Coefficient	0.738523	0.652265
R^2	64.5%	57.4%

Table 5.6.1.7
Effect on ASM Regression Line
For NO_X Emissions
Of Deleting Vehicle 3202

	Based on All 52 Vehicles	Based on 51 Vehicles
Constant	-0.013624	-0.003336
Coefficient	0.829714	0.816328
R^2	70.8%	60.1%

Six vehicles (vehicle numbers: 3172, 3200, 3212, 3239, 3240, and 3244) exhibited large decreases in lane NO_X emissions, but little if any change in FTP NO_X emissions. These six had a number of factors in common:

- All six had low as-received FTP HC (for five of the six HC ^{2} 0.37, and HC = 0.59 for the sixth), CO (CO ^{2} 3.47), and NO_X (NO_X ^{2} 2.34).

- All six had low as-received lane-IM240 HC (HC ^{2} 0.29) and CO (CO ^{2} 3.33), but high lane-IM240 NO_X (NO_X ^{3} 1.14).

- All six had low as-received ASM composite HC (HC ^{2} 0.24) and CO (CO ^{2} 4.53).

  -- Five of the six had as-received ASM composite NO_X ^{3} 1.07.
  -- Four of the six had as-received ASM composite NO_X ^{3} 1.58.
  -- Three of the six had as-received ASM composite NO_X ^{3} 2.39.

- All six had ambient temperatures between 61° and 80° F.

As previously noted, many vehicles exhibited little, if any, change in a particular pollutant (either HC, CO, or NO_X) because the initial (as-received) test results for that pollutant were relatively low (i.e., those vehicles had been recruited because one of the other two pollutants exceeded its cutpoint). The effects of including those vehicles in the analysis (which was done in the preceding analysis) is to increase the number of vehicles clustered near the origin (Figures 5.6.1.1 through 5.6.1.3) and, in the regression analysis (Tables 5.6.1.2 and 5.6.1.3), to increase the weighting applied to those points clustered near the origin. Thus, by restricting the analysis to only those vehicles that exceeded the as-received cutpoint for each pollutant , those two situations are eliminated. The three resulting data bases are:

1) the 32 (of the 52) vehicles that were recruited (and repaired) because their initial lane-IM240 exceeded the HC cutpoint of:

   Composite IM240 HC > 0.80 and Mod e-2 IM240 HC > 0.50.

2) the 16 vehicles that were recruited (and repaired) because their initial lane-IM240 exceeded the CO cutpoint of:

   Composite IM240 CO > 15.00 and Mode-2 IM240 CO > 12.00.

3) the 30 vehicles that were recruited (and repaired) because their initial lane-IM240 exceeded the NO_X cutpoint of:

   Composite IM240 NO_X > 2.00.

As previously discussed, two vehicles (vehicles numbered 3211 and 3190) could be deleted from the “HC-Repaired” and from the “CO-Repaired” data bases due to questionable test results. Additionally, vehicle number 3202 could be deleted from the “NOx-Repaired” data base for similar reasons. Thus, in addition to performing regression analyses on the entire 52 car data base, we can also perform regressions on the 32/16/30 (HC/CO/NO_X) subsets, as well as, (after deleting the questionable vehicles) on the 30/14/29 car subsets. Within these various data sets, we performed 16 linear regressions, the results of which are summarized in Tables 5.6.1.8 through 5.6.1.10.

Table 5.6.1.8

Regression Lines of ÆHC for Short Tests Versus FTP

	------------ IM240 ------------			------------- ASM -------------		
	Based on All 52 Vehicles	Based on 32 Exceeding Initial HC	Based on 32 Minus Two	Based on All 52 Vehicles	Based on 32 Exceeding Initial HC	Based on 32 Minus Two
Constant	-.365173	-.932339	0.014741	.270944	0.371352	0.7929
Coefficient	1.41060	1.63036	0.958254	2.18967	2.14853	1.11862
R-Squared	81.9%	82.7%	63.3%	71.7%	67.2%	60.9%

Table 5.6.1.9

Regression Lines of ÆCO for Short Tests Versus FTP

	------------ IM240 ------------			------------- ASM -------------		
	Based on All 52 Vehicles	Based on 16 Exceeding Initial CO	Based on 16 Minus Two	Based on All 52 Vehicles	Based on 16 Exceeding Initial CO	Based on 16 Minus Two
Constant	4.64057	17.5097	-0.36712	5.71775	13.9744	13.4061
Coefficient	0.846373	0.611959	1.28527	1.08685	0.95755	0.962594
R-Squared	47.5%	18.7%	55.1%	79.5%	73.0%	74.1%

Table 5.6.1.10

Regression Lines of ÆNOx for Short Tests Versus FTP

	------------ IM240 ------------			------------- ASM -------------		
	Based on All 52 Vehicles	Based on 30 Exceeding Initial NOx	Based on 30 Minus One	Based on All 52 Vehicles	Based on 30 Exceeding Initial NOx	Based on 30 Minus One
Constant	-.275563	-.778908	-0.45849	-0.013624	0.209571	0.273927
Coefficient	0.738523	0.886525	0.733666	0.829714	0.763686	0.711124
R-Squared	64.5%	54.2%	39.9%	70.8%	62.3%	45.7%

Examining the slopes and y-intercepts (i.e., the “coefficient” and “constants” in Tables 5.6.1.8 through 5.6.1.10) of the 18 regression lines, we make the following observations:

- Limiting the analysis to only those vehicles whose initial lane-IM240 test exceeded the cutpoint for the pollutant being examined:

  -- had virtually no effect on the regression line predicting FTP HC changes based on ASM HC changes, and only a relatively small effect on the line predicting FTP CO changes based on ASM CO changes;

  -- had moderate effects on the two regression lines predicting FTP HC and CO changes based on IM240 HC and CO changes; and

  -- had only relatively small effects on the regression lines predicting FTP NOx changes based on ASM or IM240 NOx changes. Again, the effect was larger for the IM240 case.

- Deleting the one or two questionable vehicles prior to performing the regression analysis:

  -- produced only small effects in the two NOx cases (IM240 and ASM) and in the ASM CO case and

  -- produced substantial effects in the two HC cases and in the IM240 CO case.

In summary, this analysis indicates that the change in ASM scores before and after repairs correlates with changes in FTP emissions, about as well as for the IM240. However, because ASM cutpoints were not recommended by ASM proponents and EPA did not have cutpoints to use as repair targets, the contractor repairs were performed to attain IM240 scores that complied with the standard IM240 cutpoints. So the contractor repairs offer little insight into the primary question of whether vehicles repaired to pass an ASM test will be as effective as vehicles repaired to pass the IM240 test. The next two sections will further discuss repair issues.

5.6.2 Commercial repairs

5.6.2.1 Introduction

The purpose of this analysis was to compare the effects of commercial repairs, for vehicles that failed the Arizona I/M test, on IM240 and ASM after-repair test results. Experience has shown that commercial repairs geared to steady-state I/M tests have not met expectations for in-use emission reductions. Because vehicles are operated only at steady-state, repairs have been geared to reducing emissions at those operating conditions. As a result, emissions over the full range of operating conditions are often not effectively reduced, even when vehicles are repaired to pass a steady-state I/M test. This is one reason EPA has established a transient test for enhanced I/M. Since the IM240 requires vehicles to perform over a wide variety of real-world operating conditions, IM240-successful repairs must be effective in reducing emissions over a wide range of operating conditions.

By comparing the effects of commercial repairs on ASM and IM240 test results at selected cutpoints, an evaluation of the comparative repair effectiveness can be made. As discussed above, EPA analyzed the results of repairs performed to pass the Arizona I/M test to determine whether such repairs would significantly reduce ASM emissions without significantly reducing FTP emissions. Since the ASM test and the Arizona I/M test are somewhat similar in that they are steady-state tests, repairs for the Arizona I/M test may provide information on whether ASM-successful repair are as effective as IM240-effective repairs.   The data show that successful repairs for the Arizona I/M test are more likely to be successful for the ASM test than for the IM240.

5.6.2.2 Database/Analysis

EPA's commercial repair program in Mesa consisted of offering incentives to owners of 1983 and newer vehicles that failed the Arizona I/M test, but were not needed or declined to participate in laboratory testing, to return to EPA's IM240 lane for after-repair ASM and IM240 tests. To receive their incentive, they were told to return with a receipt for commercial repairs. No instructions were given to owners regarding where or how to get their cars repaired, and owners were not compensated for the actual repair itself.

As of April 1, 1993, before- and after-repair data were available for 23 of these vehicles. One vehicle, #13239 (CR# 24) was removed from the database due to unacceptable speed deviations on its initial ASM test, leaving 22 vehicles available for analysis. For this analysis, five other vehicles were excluded because they continued to fail the Arizona test after repairs. The resulting database consisted of 17 successfully repaired, 1983 and newer vehicles.

Cutpoints were applied to the IM240 and ASM data to determine pass/fail status. The pass/fail determinations were then compared to evaluate the effects of commercial repairs. Three different cutpoint sets were used to make the comparisons. Since the Arizona test measures HC/CO only, the first comparisons involved only HC and CO criteria. Two additional comparisons were made which included NOx cutpoints. All three are listed below (Section 5.3 discusses the relevance of these cutpoints.):

- IM240 recommended cutpoints for HC/CO with ASM cutpoints that produce the highest IDRs at the same failure rate as the IM240 recommended cutpoints:

  IM240 - 0.80 / 15.0 + 0.50 / 12.0
  ASM - 1.00 / 8.0

- EPA recommended IM240 cutpoints including NOx with ASM cutpoints that produce the same 18% failure rate. These cutpoints are listed below:

  IM240 - 0.80 / 15.0 / 2.0 + 0.50 / 12.0
  ASM - 1.00 / 8.0 / 2.0

- ASM and IM24O cutpoints selected to achieve the highest IDRs possible while keeping the probable Ec rate below 5%. These cutpoints are listed below:

  IM240 - 0.30 / 9.0/ 1.7 + 0.19 / 7.0
  ASM - 0 .40 / 8.0 / 1.5

For each set of cutpoints, a comparison of the initial and final test results were made. To evaluate the effects of repairs on a specific I/M test a vehicle must be identified by the I/M test for repairs. Thus, while the initial test result comparison allowed the identification ability of these two I/M tests to be compared, the final test result allows an evaluation of the relative repair effectiveness of the I/M tests. The data were restricted to vehicles which were identified by all tests for the comparison of final test results. Using these common vehicles allows the comparison of repair effects to be clearly illustrated.

The results, which are discussed in the next section, indicate that the IM240 is superior at identifying vehicles requiring repair and that for vehicles which initially fail both the IM240 and ASM, steady-state repairs are more likely to result in ASM passing scores than in IM240 passing scores.

5.6.2.3 Results/Conclusions

Initially, all 17 vehicles used in this analysis failed their initial Arizona I/M test. However, the IM240 and ASM identified slightly different sets of vehicles as needing repairs. Vehicles of interest are those that pass the initial IM240 and fail the initial ASM and those that fail the initial IM240 and pass the initial ASM.

As shown in Table 5.6.2-1, for the initial HC/CO only comparison, one car passed the IM240 and failed the ASM and four cars passed the ASM and failed the IM240 (see Appendix B for data listings). These errors-of-omission support the assertion made in Section 5.3 that the ASM is weaker than the IM240 at identifying malfunctioning vehicles with HC and/or CO emission problems.

Table 5.6.2-1
Initial Pass/Fail Status Comparison

HC/CO only Cutpoints			**Common Failure Rate Cutpoints**			**Optimal IDR/Max Ec Cutpoints**		
IM240 PASS	**ASM** PASS	3	**IM240** PASS	**ASM** PASS	2	**IM240** PASS	**ASM** PASS	1
IM240 FAIL	**ASM** PASS	4	**IM240** FAIL	**ASM** PASS	2	**IM240** FAIL	**ASM** PASS	2
IM240 PASS	**ASM** FAIL	1	**IM240** PASS	**ASM** FAIL	0	**IM240** PASS	**ASM** FAIL	0
IM240 FAIL	**ASM** FAIL	9	**IM240** FAIL	**ASM** FAIL	13	**IM240** FAIL	**ASM** FAIL	14

Vehicle 13504 (CR# 25) failed the ASM and Arizona test due to a CO problem which appears to occur only at idle operation. Because the IM240 driving cycle includes little idle operation, this vehicle was not identified by the IM240 HC/CO only cutpoints. An air/fuel mixture adjustment reduced emissions sufficiently to pass the HC/CO cutpoints for the ASM and Arizona tests. However, this vehicle did exhibit excessive NOx emissions that were identified by the addition of a NOx cutpoint. Incidentally, the fuel mixture adjustment did little to address or reduce this vehicle's NOx emissions on either the IM240 or the ASM.

In contrast to the IM240, which failed to identify only one vehicle, four vehicles passed the ASM HC/CO only cutpoints and failed the IM240 and Arizona cutpoints. Three of these vehicles are examples of ASM errors-of-omission and illustrate the superior identification ability of the IM240. The fourth vehicle failed NOx and will be discussed after the three that passed.

Vehicle 13471 (CR# 27) failed the Arizona and IM240 tests because of high CO emissions, but passed the ASM test. Vehicle 13125 (CR# 12) failed HC on both the IM240 and Arizona tests and was not identified by the ASM cutpoints. Vehicle 13202 (CR# 15) failed the HC and CO idle modes of the Arizona test. On the IM240, vehicle 13202 failed HC and NOx but passed CO due to the two-ways-to-pass algorithm. The ASM identified this vehicle for NOx emissions only.

The fourth vehicle that initially passed only the ASM test was vehicle 12771 (CR# 8). This vehicle exemplifies the weakness of steady-state I/M tests and is discussed in detail in Section 5.6.3. Vehicle 12771 failed CO on the loaded mode of the Arizona test but passed the CO cutpoint on both the IM240 and the ASM. However, the car failed NOx and HC on the IM240 and failed only NOx on the ASM. After repair, this car passed both the ASM and Arizona tests even when ASM cutpoints were tightened. These repairs did not sufficiently reduce emissions over the full operating range of the vehicle, demonstrated by the vehicle continuing to fail both HC (1.01 g/mi) and NOx (3.01 g/mi) on the IM240. This supports the assertion made in the introduction that repairs to pass a steady-state test may not be effective in reducing emissions over normal driving conditions and, therefore, do not effectively reduce in-use emissions.

To illustrate the effects of commercial repairs on ASM and IM240 after-repair test results, data were restricted to vehicles that failed both the initial ASM and IM240 (see Table 5.6.2-1). The results of these comparisons are graphically depicted in Figures 5.6.2-1 thru 5.6.2-3.

Figure 5.6.2-1
Commercial Repairs Passing ASM and IM240 Cutpoints
HC/CO only Comparison

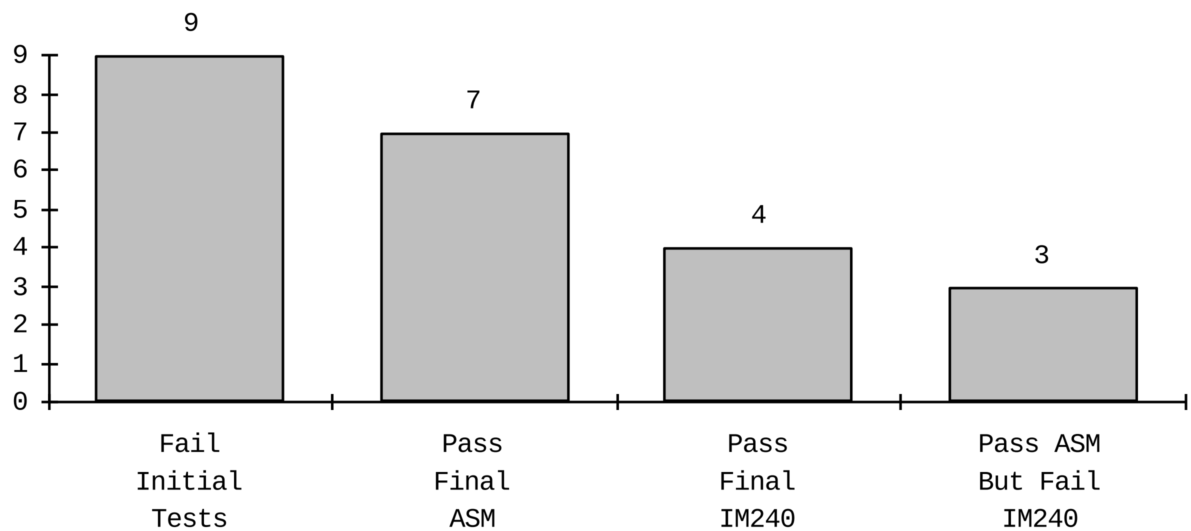


Figure 5.6.2-2
Commercial Repairs Passing ASM and IM240 Cutpoints
Common Failure Rate Comparison

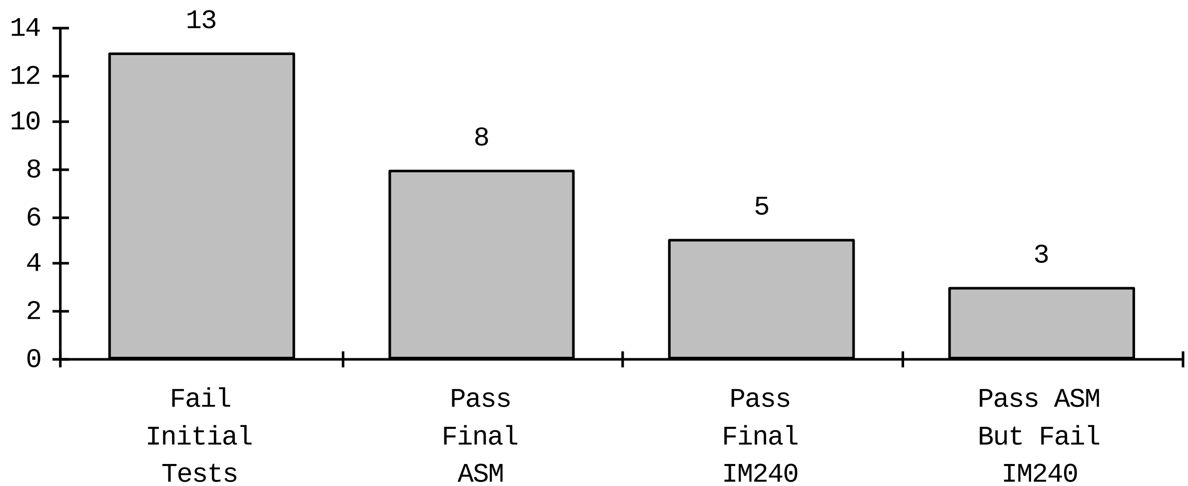
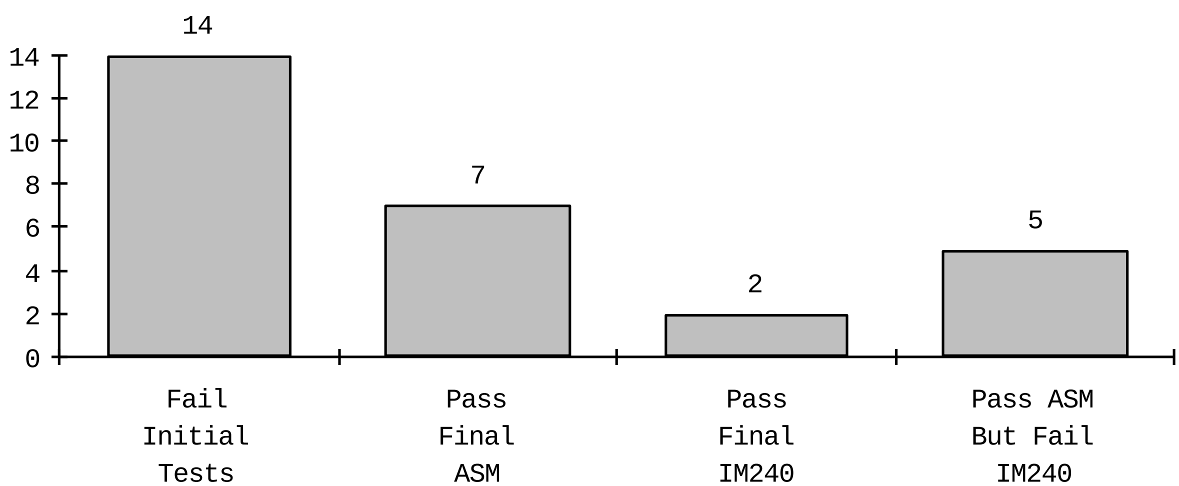


Figure 5.6.2-3
Commercial Repairs Passing ASM and IM240 Cutpoints
High Ec Comparison



These graphs show that vehicles can and will be repaired to pass the ASM test but will continue to fail the IM240.

For the first comparison using only HC and CO cutpoints, three vehicles passed the ASM but continued to fail the IM240. The second comparison added the NOx cutpoint which in combination with the HC/CO cutpoints produced the same failure rates for the IM240 and ASM. Again, three vehicles passed the ASM but continued to fail the IM240. For the comparison using the most stringent cutpoints for the IM240 and ASM, five vehicles passed the ASM but continued to fail the IM240. For all of these comparisons, there were no vehicles that failed the ASM and passed the IM240 after commercial repairs. This indicates that repairs which are sufficient to pass the ASM test are not necessarily sufficient to pass the IM240, indicating that the repair effectiveness of the IM240 is superior to that of the ASM.

Based on these results, repairs to pass the steady-state Arizona I/M test are significantly more effective at reducing ASM emission scores than IM240 emission scores. Although the sample of successful commercial repairs is small, these results indicate that the ASM test, if implemented, will result in significantly lower identification rates and emission reduction benefits than those of the IM240. A more detailed investigation of ASM emission reduction benefits is discussed in Section 5.6.3.

5.6.3 In-Use Emission Reductions from Real World Repairs

One of the concerns with any test is the ability of an observed reduction on the test to reflect real and permanent in-use reductions. Two particular concerns are (1) can unscrupulous mechanics find repair strategies that would allow a vehicle to temporarily pass the I/M test without resulting in permanent in-use reductions (i.e., temporary repairs would be undone after passing the test), and (2) is the test sufficiently imprecise such that honest, but insufficient, repairs would not be detected by the I/M retest.

Test Defeating Strategies

It is common knowledge that the current idle test can be, and is being, defeated by a variety of methods. Most can be used only in the privacy of a test-and-repair station. Some of the common ones that can be used in a test-only station include creating a vacuum leak to lean out the air-fuel ratio for CO failures, and raising the idle speed to create a similar effect. A logical question is, what is the likelihood that test defeating strategies can be developed by unscrupulous mechanics for the ASM or for the IM240 I/M tests.

On the surface, the ASM test appears easier to beat than the IM240 because of its steady-state nature and number of limited operating modes. In theory at least, the mechanic could employ a similar method to the idle test for ASM CO failures. The process would include creating a vacuum leak and disabling the feedback control system. Since it is assumed that most shops would have a dynamometer in an ASM I/M scenario, the mechanic would simply need to operate the vehicle on the dynamometer and adjust the leak until the car was under the cutpoints. Most likely the driveability of the car would be quite poor; however, it would only need sufficient driveability to drive to the test center and return, where the test beating repairs could be undone.

If the vehicle could drive to the test center, then it could certainly drive the steady-state test, since driveability is not required on the ASM, and emissions are not recorded during the transitions between ASM test modes. Conversely, the emissions are measured during driving transitions on the IM240, and the lack of driveability would require more throttle movement with a likely substantial increase in CO emissions. If misfire occurred during driving transitions because of the lean condition, the HC, and possibly NOx, would increase on the IM240, but would not on the ASM (because emissions are not measured during driving transitions).

Another potential test defeating strategy that could occur on the ASM for NOx failures deals with ignition timing. Retarding ignition timing has long been an approach to reducing NOx. Retarding the ignition timing excessively, however, reduces driveability. Once again, however, driveability is not required on the ASM. A severe loss in driveability on the IM240 would be expected to increase CO significantly, but would be expected to have little effect on the ASM CO levels.

Some may point out that many new cars do not have adjustable distributors, and others do not have distributors at all. Therefore, it would not be possible to retard the timing, so such a test defeating strategy would not exist on these cars. What many may not know is that all cars with non-adjustable distributors and those without distributors have a base timing mode that can be activated. Activation of base timing will severely retard the timing in most cases, and could be used to lower NOx emissions.

Since these are only a few of the less creative methods that might be attempted to defeat an ASM or IM240 test, it would be useful to verify if the theoretical potential really could occur. Currently there is no data on purposefully test defeating repairs. However, data from vehicles tested in Arizona and sent for commercial repair may shed some light on the potential for test defeating or improper repairs to be identified by either the ASM or the IM240.

In our commercial repair data base, twenty-two vehicles failed the Arizona I/M test which includes a steady-state loaded mode and an idle mode. All of these vehicles received a 4-mode ASM test and an IM240 test. The vehicle owners took the vehicles for commercial repair, and volunteered for repeat ASM and IM240 tests when they returned for their Arizona retest.

Five of the 22 vehicles were excluded from this analysis because their four-mode ASM emissions did not exceed the cutpoints of 1.0/8.0/2.0 (HC/CO/NOx). The resulting 17 vehicles represent the portion of the 22 car sample that would have failed a four-mode ASM test if that had been the official test. Note that this group of 17 vehicles represents a different portion of the sample of 22 commercially repaired vehicles than the 17 vehicles used for analysis in Section 5.6.2. The analysis in Section 5.6.2 excluded five vehicles that ultimately did not pass the Arizona I/M test after repairs. The analysis in this section excluded five vehicles that passed the initial ASM test, but included those vehicles that did not ultimately pass the Arizona I/M test after repairs.

The repairs conducted on the 17 vehicles are listed in Table 5.6.3-1. From these repairs and the resulting ASM and IM240 scores, the possibility of test defeating strategies can be evaluated. Note that the multiple repairs represent retest failures on the Arizona

I/M test. Also, four of the 17 vehicles that initially failed the ASM test did not ultimately pass the Arizona I/M test.

The before and after repair emission results are graphically represented in Figures 5.6.3-1 though 5.6.3-3. From the repair data reported by the commercial garages (in Table 5.6.3-1), it is clear that many vehicles had the air-fuel ratio adjusted or received repairs that would likely affect air-fuel ratio. Many of the vehicles were feedback carbureted; however, this should make no difference for the purposes of evaluating the effect of air-fuel ratio on the test type. Only vehicles CR-07 and CR-16 had reported commercial repairs that would not likely affect air-fuel ratio (it was assumed that the "tune-up" repairs in Table.5.6.3-1, in some cases, could have involved adjustment of air-fuel ratio).

On these other vehicles, the degree of the effect on air-fuel ratio is unknown. But, from the CO emission results in Figure 5.6.3-2, it is clear that in general, a repair that resulted in reduced CO on the IM240 also reduced CO on the ASM. However, there are some exceptions. These are vehicles CR-10, and CR-25. Vehicle CR-10 failed the before and after IM240, failed the before-ASM, but passed the after-ASM. Whereas vehicle CR-25 passed the before and after IM240, failed the before-ASM, and passed the after-ASM.

Since CO is primarily a function of air-fuel ratio, the observation from these two vehicles is that the air-fuel ratio during the steady-state test can be different than the average over the transient test. To some extent, this observation also appears to be evident in the CO results for vehicles CR-03, CR-06, and CR-22 (see Figure 5.6.3-2). In the case of vehicle CR-10, the air-fuel ratio during steady-state operation is sufficiently lean after repairs to allow the vehicle to pass the ASM, but rich enough overall during transient driving to cause an IM240 failure. The opposite is apparently true for vehicle CR-25, where the before repair air-fuel ratio during steady-state is apparently sufficiently rich to cause an ASM failure, but lean enough during average driving to allow the vehicle to pass the IM240.

Certainly, the CO level can also be affected by the catalyst. But the catalyst was the same in all of these tests, so the catalyst effect should wash out. Also, catalyst efficiency can be somewhat gauged by HC levels as seen in Figure 5.6.3-1. The after repair HC levels on vehicle CR-10 clearly pass the ASM cutpoint. The after repair IM240 HC status parallels the CO status. In other words, based on the IM240 this vehicle was still broken, but was passed on the ASM. The HC levels on vehicle CR-25 were low for all IM240 and ASM tests. Based on IM240 results, this vehicle should not have been failed for HC or CO. However, vehicle CR-25 did have serious problems as evidenced by the NOx emissions in Figure 5.6.3-3.

The emission results on these two vehicles, reinforce the following point. Air-fuel ratio can affect the CO levels on both tests. In particular, the air-fuel ratio during a steady-state mode can be different than the overall ratio during transient operation. Therefore, it is likely that with willful intent, a mechanic could purposefully create a vacuum leak, and adjust it so that a car could pass the ASM, but not the IM240. Whereas the amount of leanness in vehicle CR-10 was not sufficient to pass CO on the IM240, it was sufficient to pass the ASM. Furthermore, the amount of leanness was not sufficient to cause vehicle CR-10 to fail either the IM240 or the ASM NOx cutpoints. Therefore, the results on vehicle CR-10 support the theoretical possibility that unscrupulous mechanics could, with proper adjustment of vacuum leaks, be able to adjust vehicles to temporarily pass the ASM CO without increasing the NOx emissions sufficiently to cause an ASM NOx failure. As indicated previously, the likelihood of such improper and temporary repairs would be exacerbated in a program where the ASM was the official test, because unscrupulous repair centers could conveniently maladjust a vehicle on a dynamometer to pass the steady-state modes of the ASM test.

Table 5.6.3-1

Vehicle Repairs

VEH.NO	1st Repair	2nd Repair	3rd Repair
CR-01	Adjusted air/fuel mixture on carburetor.	Rpred electrical short in harness from ECU to mix control.	
CR-02	Adjusted air/fuel mixture on carburetor.		
CR-03	Adjusted air/fuel mixture on carburetor. Replaced heat valve.		
CR-04	Repaired vacuum leak and adjust ignition timing.		
CR-05	Replaced O2 Sensor and performed TuneUp.		
CR-06	Rpl O2 ,plugs, cap and rotor, cleaned fuel injector	Adjusted Idle, air/fuel mixture, cleaned fuel injectors.	
CR-07	Rpl fan belt, plugs, fuel flt. Adj timing. Changed oil.	A one year waiver was granted for this vehicle.	
CR-08	Tune - up, replaced fuel filter, replaced air filter.		
CR-09	Adjusted emissions. Scoped and adjusted air/fuel mixture.		
CR-10	Adjusted air/fuel mixture and idle speed.	Adjusted air/fuel mixture and idle speed.	
CR-13	Adjusted air/fuel mixture, idle speed.		
CR-15	Replaced Oxygen sensor.		
CR-16	Set Ignition timing to manufacturer's specifications.		
CR-21	Tune-up,Rpl plugs, wires, distributor cap and rotor.	Performed Tune-up.	
CR-22	Checked proper operation of choke and repaired.	Scoped engine and adjusted carburetor.	Overhauled Carburetor.
CR-25	Adjusted air/fuel mixture and idle speed.		
CR-26	Performed basic tune up.		

Figure 5.6.3 - 1

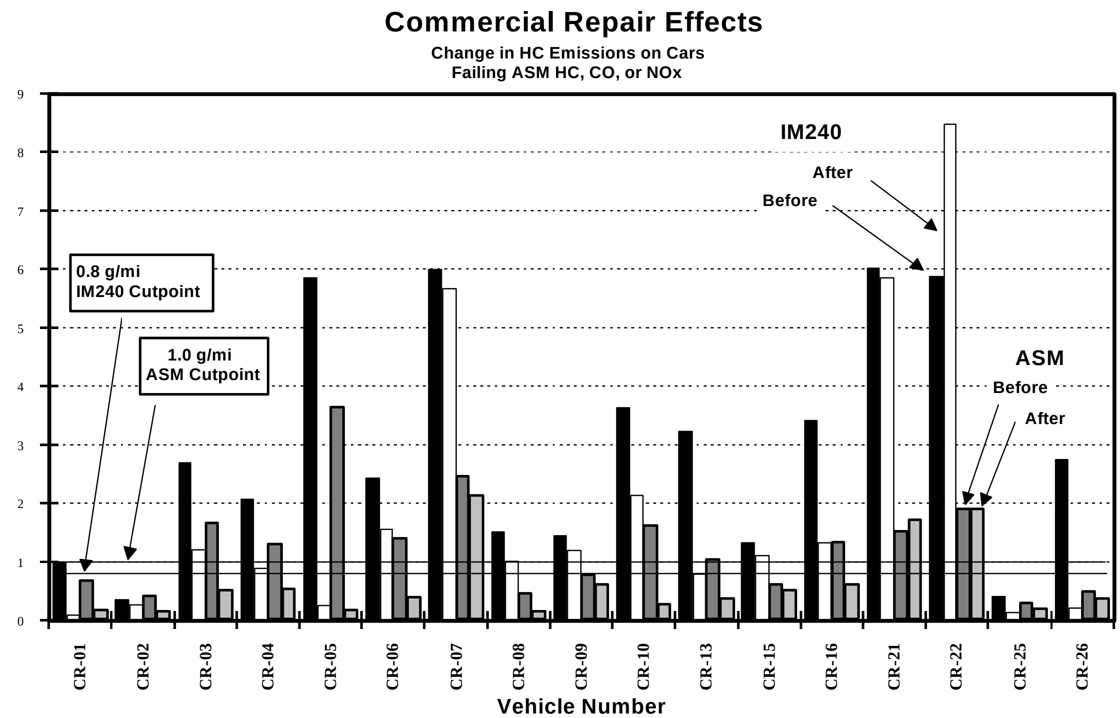


Figure 5.6.3 - 2

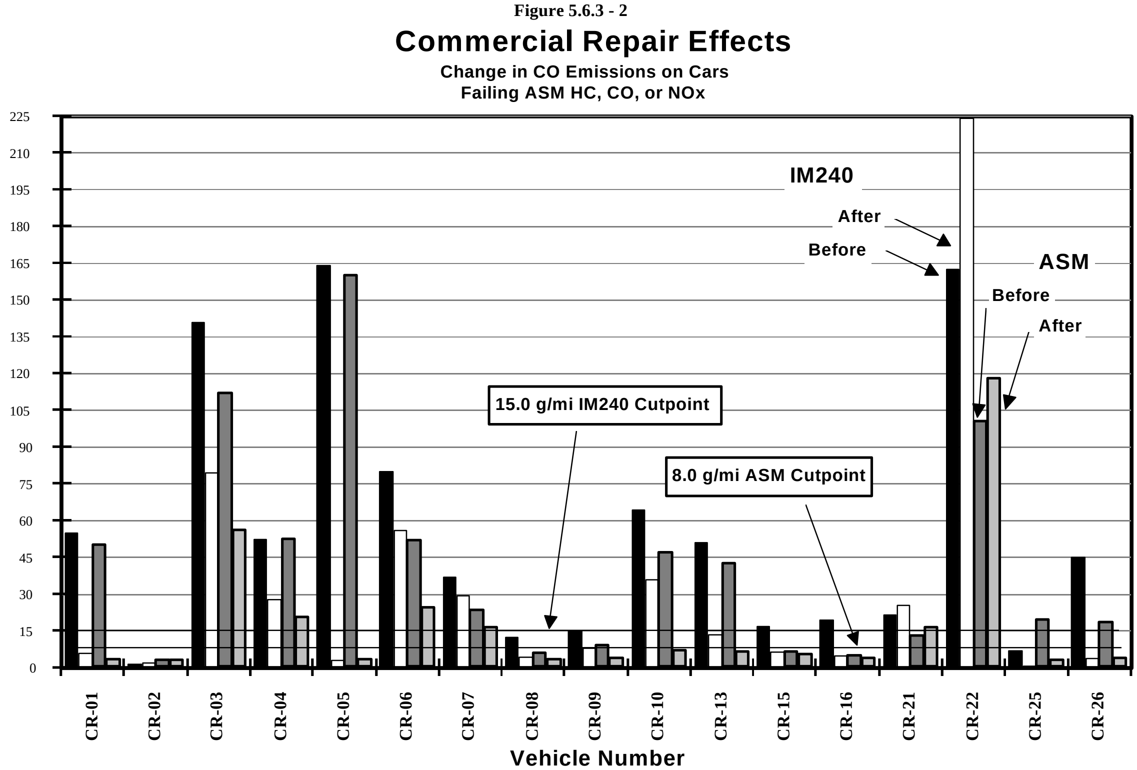
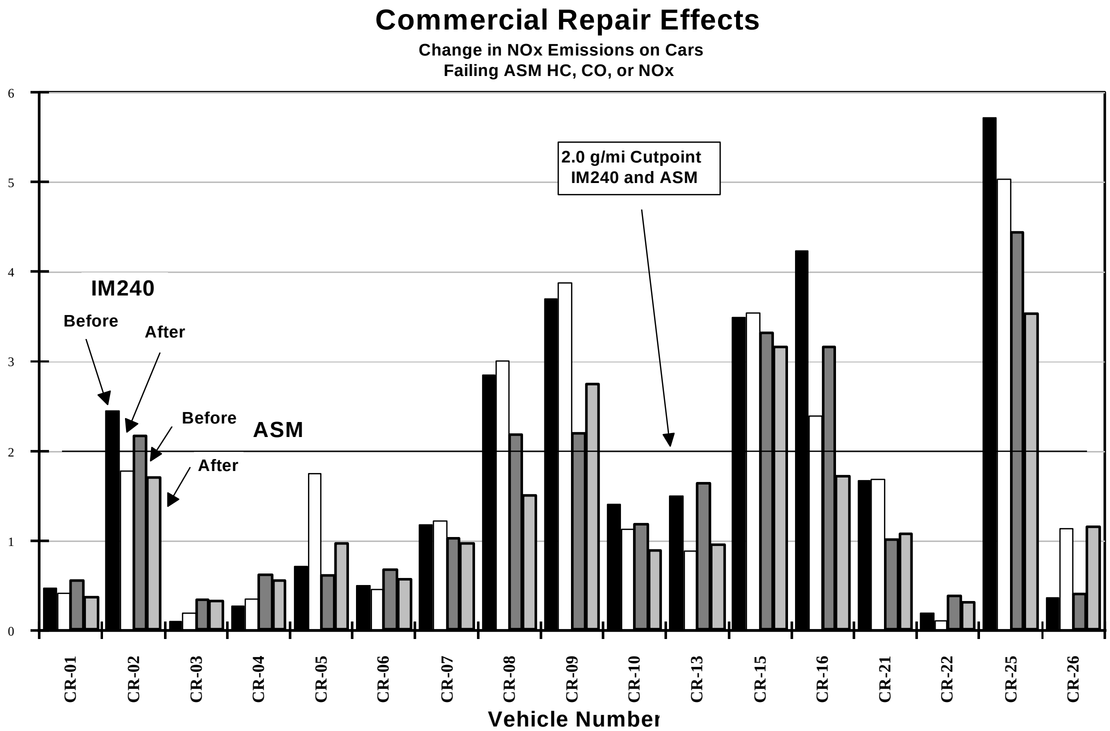


Figure 5.6.3 - 3



Insufficient Repairs

Another concern with an I/M test is the ability for the test to cause proper and sufficient repairs to be performed if the vehicle fails the I/M test. For this analysis, proper and sufficient repairs are considered to be repairs sufficient to pass the IM240 cutpoints. The commercial repair data used in the preceding section on test defeating strategies can also provide some insight into this issue.

Of interest is the comparison of test modes between the 4-mode ASM and the Arizona I/M test. Both have an idle mode, and both have a steady-state loaded mode. The Arizona loaded mode is similar to the ASM 2525 mode.

Using the general similarity of the test (i.e., idle and loaded modes), the general sufficiency of ASM repairs can be approximated by observing the results from vehicles used in the previous section that failed the initial ASM test and the initial Arizona I/M test. A case history on vehicle number CR-08, which initially failed the IM240 HC and NOx cutpoints (as well as the Arizona CO cutpoint and the ASM NOx cutpoint), illustrates the concern about the ability of the ASM test to cause proper and sufficient repairs to occur in-use.

After vehicle number CR-08 had failed the Arizona I/M test for CO on January 4, and had received initial tests on the IM240 and ASM, it was enlisted in the commercial repair program. Two weeks after the commercial repairs (January 14), the vehicle returned for its after-repair IM240, ASM, and Arizona I/M retest (and for the owner to obtain the recruitment incentive payment). At that time, it was discovered that two days after the initial I/M test (which was conducted on January 4), and following repairs (listed in Table 5.6.3-1), the repair center had taken the vehicle to another Arizona test lane for an I/M retest. At this other I/M lane, on January 6 the vehicle easily passed the Arizona cutpoints of 1.2% CO and 220 ppm HC. However, when retested on January 14 at the IM240 test lane, this vehicle failed the Arizona HC cutpoint by a wide margin (see Table 5.6.3-2). The owner was demonstrably upset (even though a valid Arizona passing certificate had been issued), and left the test center abruptly. However, the owner returned again in another two weeks (January 26). At this time, the vehicle passed all of the Arizona cutpoints. The owner did not divulge any information on corrections or repairs that may have occurred between January 14 and January 26.

Table 5.6.3-2

Test Data - Vehicle No. CR-08

			State Test				IM240			ASM		
			Loaded		Idle							
Date	Operation	Lane#	HC ppm	CO %	HC ppm	CO %	HC g/mi	CO g/mi	NOx g/mi	HC g/mi	CO g/mi	NOx g/mi
1/04/93	Lane IM240	2771	86	1.55	87	0.38	1.51	12.2	2.85	0.46	5.7	2.19
1/06/93	State Test	---	40	0.84	116	0.78	---	---	---	---	---	---
1/14/93	Lane IM240	2977	38	0.63	835	0.07	1.38	4.1	2.59	0.33	3.5	1.63
1/26/93	Lane IM240	3168	75	0.38	41	0.06	1.01	4.4	3.01	0.16	3.4	1.51

Several important aspects should be noted. First, while this vehicle failed the Arizona CO cutpoints, it passed CO on all ASM and IM240 tests. Also, while this vehicle passed HC in all of ASM tests, it failed HC on all of the IM240 tests. Further, after the first repair, this vehicle passed the ASM NOx cutpoints for all subsequent ASM tests, even though it failed the IM240 NOx cutpoints for all of the subsequent IM240 tests (as well as the initial IM240). The IM240 NOx actually increased slightly from the first test to the last.

The most pessimistic scenario on this vehicle is that once the vehicle failed the Arizona test for CO, the mechanic maladjusted the vehicle, took it to an I/M lane, where it passed, and then undid the maladjustments. These undid maladjustments were then observed on the January 14 Arizona retest. A more benign conclusion is that the mechanic performed incomplete repairs, but the repairs were ultimately sufficient to pass the Arizona test. Also, the repairs were sufficient to pass the ASM NOx cutpoints (HC and CO were always below the ASM cutpoints), while they were not sufficient to pass the IM240 NOx cutpoint, nor were they sufficient to pass the IM240 HC cutpoint. In fact, the ASM would not even have identified this vehicle as a high HC emitter.

Clearly, on this particular vehicle, commercial repairs were not sufficient to pass the IM240, but were sufficient to pass the ASM test.

Reviewing the data for all 17 vehicles that failed the initial ASM test, all of these vehicles, except CR-07, CR-21, and CR-22 eventually passed the Arizona HC I/M retest. Also, all vehicles, except these three vehicles and CR-06 eventually passed the Arizona CO I/M retest.

However, vehicles CR-03, CR-04, CR-06, CR-08, CR-09, CR-10, CR-15, and CR-16 which initially failed the IM240, continued to fail HC on the IM240 after all commercial repairs (see Figure 5.6.3-1). Further, after all commercial repairs, these same vehicles passed the ASM HC cutpoint (note CR-8, CR-9, and CR-15 passed the initial ASM test, see Figure 5.6.3-1). Given the similarities of the ASM and the Arizona test, these data suggest that the level of HC repair on the ASM would be similar to the current Arizona I/M test. This assumption on test similarity and stringency of repair effectiveness is further supported by the fact that the three vehicles that failed to pass the Arizona test after repairs (CR-7, CR-21, and CR-22) were also the only vehicles that failed the after-repair ASM test (see Table Figure 5.6.3-1).

Another method of looking at the ability of the ASM to enforce proper and sufficient repairs is to look at the test status of the ASM results before and after repairs relative to the before and after IM240 status. The test status for the 17 vehicles initially failing the ASM for at least one pollutant is listed in a truth-table format in Table 5.6.3-3 by pollutant (i.e., HC, CO, and NOx). The roughly square boxes in a diagonal row represent test results where the IM240 and ASM status before and after repair were identical. Deviations from the diagonal row, obviously represent results where the status differs between the IM240 and ASM. The fuzzy horizontal rectangular box in Table 5.6.3-3 highlights those vehicles which passed the ASM test after repair, but were still failing the IM240 for HC, CO, or NOx.

From the Table, a total of 11 vehicles continued to fail the IM240 HC cutpoint after repair. Of these 11 vehicles, 8 vehicles (or 73%) passed the ASM after repair (three of the eight also passed the initial ASM test). All eight vehicles also passed the Arizona HC cutpoint after repair. As previously mentioned, in the 11 vehicle sample that continued to fail the IM240 HC cutpoint, 100% of the vehicles that failed the Arizona HC cutpoint (CR-07, CR-21, and CR-22), also failed the ASM HC cutpoint. Thus, every vehicle that continued to fail the Arizona HC cutpoint also continued to fail the ASM HC cutpoint. In other words, in this sample of commercial repairs, the ASM did not fail anymore retest vehicles than the Arizona I/M test.

CO test status represents somewhat of a mixed bag. Seven vehicles continued to fail the IM240 for CO after repair. Only one vehicle in this group of seven (or 14%) passed the ASM for CO after repair. This vehicle also passed the Arizona retest. In this seven vehicle sample that continued to fail the IM240 CO cutpoint, six vehicles continued to fail the ASM, and four vehicles (CR-06, CR-07, CR-21, and CR-22) failed the Arizona retest. In this case, the ASM found 2 more vehicles than the Arizona I/M retest after commercial repairs.

However, it should be noted, that four other vehicles had anomalous CO results. Two vehicles, CR-15 and CR-16 failed the initial IM240 for CO, passed the initial ASM, and subsequently passed both the IM240 and ASM for CO. Two other vehicles (CR-09 and CR-25), passed the initial IM240, failed the ASM for CO, and also subsequently passed both the IM240 and ASM retests. If the ASM was as good as the IM240 in identifying vehicles that should fail a retest (at the same overall failure rate), one might expect a random scatter on each side of the diagonal boxes, particularly for vehicles just marginally failing or passing (which all of these were, except CR-25). Even so, all of these vehicles also passed the Arizona CO retest. So they do not represent any additional retest failures following commercial repairs that the ASM would have found over the standard Arizona test. Also note, that these four vehicles initially failed and continued to fail the IM240 for HC or NOx, and that the commercial repairs reduced the IM240 CO levels in all cases.

A total of 5 vehicles in this sample of 17 continued to fail IM240 NOx after commercial repairs. Two of the five (or 40%) passed the ASM after repairs. The Arizona I/M test does not test for NOx, therefore, it is more difficult to judge the effectiveness of the ASM (using the Arizona test as a surrogate) to force proper and sufficient commercial repairs.

This analysis began with a concern about the ability of the ASM test to foster proper and sufficient commercial repairs following an I/M failure. Because of the general similarity of the Arizona I/M test to the ASM, it was expected that repairs targeted by the commercial repair industry towards the Arizona test would be similar to those that would be targeted towards the ASM, at least for HC and CO. Thus, if the ASM were more effective in forcing better repairs than the Arizona test, the ASM retest should fail more cars for a given pollutant than the Arizona retest. Further, if the ASM were very effective in forcing proper repairs, it would fail as many cars, for a given pollutant, as an IM240 retest.

The analysis shows that for this small sample, the ASM fails no more cars for HC after commercial repairs than the Arizona retest, and fails only twenty-seven percent of those that failed HC on the IM240 after repair. These results imply that the ASM test would not force the repair industry to make any more repairs for high HC emissions than the current Arizona test, and obviously, not as many HC repairs as the IM240. Therefore, the data from this sample suggest that the repair effectiveness credits for HC in the MOBILE model for commercial repairs on the ASM should be no greater than that currently given for existing basic I/M programs.

The analysis for CO retest failures, indicates that the ASM found two more vehicles than the Arizona test. The Arizona I/M retest found about 57 percent of the IM240 retest failures, and the ASM found about 86 percent of the retest failures. Thus in this small sample, it appears that an ASM retest would have forced the repair industry to make additional CO repairs over and above those that would have been required to pass the Arizona cutpoints, but again, not as many as the IM240 cutpoints would require. These results suggest that the repair effectiveness credits for CO in the MOBILE model for commercial repairs on the ASM should probably be given additional credit over that currently given for existing I/M programs. The additional credit would be approximately equal to 60 percent of the difference between that currently given for existing I/M programs and that given to I/M programs employing the IM240. However, given the potential ease that unscrupulous mechanics could defeat the CO portion of the ASM retest, assigning additional CO repair effectiveness credits in the model for ASM over those currently given for existing I/M programs would be difficult to rationalize at this time.

The analysis for NOx retest failures is somewhat hampered by the fact that the Arizona test only fails vehicles for HC and CO. Even though the repair industry was not repairing vehicles to an NOx standard, the IM240 and ASM retests after commercial repairs can be used to determine whether either retest would have forced the repair industry to make additional repairs. Clearly, both tests would have required some vehicles to get additional repairs for high NOx emissions. However, the results from this sample indicate that an ASM retest would only require 60 percent of the vehicles that failed the IM240 retest to get additional NOx repairs. Therefore, this result would suggest that the repair effectiveness credits for NOx in the MOBILE model for commercial repairs on the ASM should be about only sixty percent of that given for the IM240.

Table 5.6.3-3

Effect of Commercial Repairs on Test Status

IM240 Status	ASM Status (Status Before Repair - Status After Repair)			
	Fail-Fail	Pass-Fail	Fail-Pass	Pass-Pass
Fail-Fail				
HC	CR-07, CR-21, CR-22	---	CR-03, CR-04, CR-06, CR-10, CR-16	CR-08, CR-09, CR-15
CO	CR-03, CR-06, CR-04, CR-07, CR-21, CR-22	---	CR-10	---
NOx	CR-9, CR-15, CR-25	---	CR-08, CR-16	---
Pass-Fail				
HC	---	---	---	---
CO	---	---	---	---
NOx	---	---	---	---
Fail-Pass				
HC	---	---	CR-05, CR-13	CR-01, CR-26
CO	---	---	CR-01, CR-05, CR-13, CR-26	CR-15, CR-16
NOX	---	---	CR-02	---
Pass-Pass				
HC	---	---	---	CR-02, CR-25
CO	---	---	CR-09, CR-25	CR-02, CR-8
NOx	---	---	---	CR-01, CR-03, CR-04, CR-05, CR-06, CR-07, CR-10, CR-13, CR-21, CR-22, CR-26

5.6.4 One-Mode Repairs on ASM

The objective of this analysis was to investigate the theoretical effects of targeting the ASM repairs to a single mode. That is, if it were possible for a mechanic to reduce the emissions sufficiently on a single mode while leaving the remaining three modes unaffected:

- Could an ASM failing vehicle, with such a repair, be made to pass the ASM composite cutpoint?

- What are the emission characteristics of such passing vehicles?

Examining the 106 laboratory test vehicles, we can determine whether the as-received NOx emissions met or exceeded an FTP NOx standard of 2.0 g/mi. Also, we can determine FTP HC/CO emission range. That is:

- Pass

  FTP HC ≤ 0.41 and CO ≤ 3.40 (g/mi)

- Marginal (Failing) Emitters

  FTP HC > 0.41 or CO > 3.40 (g/mi)
  and
  FTP HC ≤ 0.82 and CO ≤ 10.20 (g/mi)

- High Emitters

  FTP HC > 0.82 or CO > 10.20 (g/mi)
  and
  FTP HC ≤ 1.64 and CO ≤ 13.60 (g/mi)

- Very High Emitters

  FTP HC > 1.64 or CO > 13.60 (g/mi)
  and
  FTP HC ≤ 10.00 and CO ≤ 150.00 (g/mi)

- Super Emitters

  FTP HC > 10.00 or CO > 150.00 (g/mi)

Classifying the laboratory vehicles in this way produces ten strata; however, two of those strata are empty, and one stratum has only a single test vehicle. Using the weighting factors (Table 5.2.5.2), we can model the lane vehicles and characterize the emissions of that simulated lane sample of 2,071 1983 and new fuel-injected passenger cars. (Actually, the lane sample was 2,070 cars, the additional vehicle resulted from rounding off the estimated number of vehicles in those eight strata.) The distribution is given in the following table.

Fleet Distribution

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ^{2} 2.0	27	36	10	18	1	808	934	96	143	6
NOx > 2.0	0	4	3	7	0	0	24	18	42	0

An ASM cutpoint of 1.00/8.0/2.0 (i.e., composite ASM HC ^{2} 1.00, composite ASM CO ^{2} 8.0, and composite ASM NOx ^{2} 2.0) will fail 372 vehicles in that simulated lane fleet. The distribution of those 372 vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ^{2} 2.0	3	6	5	12	1	54	144	30	72	6
NOx > 2.0	0	3	2	6	0	0	18	12	36	0

If mechanics were able to repair those 372 vehicles so that the emissions on the 2525 mode, the 50 mph mode, and the idle mode remained unchanged, but the emissions (HC, CO, and NOx) on the 5015 mode were reduced by 80 or 90 percent (the model yields the same result for each), then only 42 of those 372 would be able to pass the 1.00/8.0/2.0 cutpoint. Thus, a repair strategy that targeted only the 5015 mode would result in “successfully” repairing only about 11 percent of the originally failing vehicles. The distribution of those 42 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing 5015 Mode by 80 or 90%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ^{2} 2.0	0	1	0	0	0	0	42	0	0	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Rather than attempting to reduce the emissions on the 5015 mode by a flat percentage, the mechanic could target the typical emissions on the 5015 mode of vehicles whose ASM composite emissions pass the 1.00/8.0/2.0 cutpoint. Such a repair strategy would not change a single failing vehicle into a passing vehicle in our model.

If mechanics were able to repair those 372 vehicles so that the emissions (HC, CO, and NOx) on the 2525 mode were reduced by 80 percent (while the emissions on the other three modes remained unchanged), then only 30 of those 372 would be able to pass the 1.00/8.0/2.0 cutpoint. The distribution of those 30 “successfully” repaired vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing 2525 Mode by 80%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	2	1	0	1	0	12	6	0	6	0
NOx > 2.0	0	1	0	0	0	0	6	0	0	0

Reducing the 2525 mode emissions by 90 percent would add 48 vehicles (42 marginal HC/CO emitters with NOx ≤ 2.0 and 6 very high HC/CO emitters with NOx > 2.0) to the 30 whose estimated ASM composite score would pass the cutpoint. Thus, a repair strategy that targeted only the 2525 mode would be successful on only 21 percent of the originally failing vehicles.

Rather than attempting to reduce the emissions on the 2525 mode by a flat percentage, the mechanic could target the typical emissions on the 2525 mode of vehicles whose ASM composite emissions pass the 1.00/8.0/2.0 cutpoint. Such a repair strategy would not change a single failing vehicle into a passing vehicle in our model.

If mechanics were able to repair those 372 vehicles so that the emissions (HC, CO, and NOx) on the 50 mph cruise mode were reduced by 80 percent (while the emissions on the other three modes remained unchanged), then 264 of those 372 would be able to pass the 1.00/8.0/2.0 cutpoint. The distribution of those 264 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing 50 mph Cruise Mode by 80%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	3	5	3	3	0	54	138	18	18	0
NOx > 2.0	0	2	2	2	0	0	12	12	12	0

Reducing the 50 mph cruise emissions by 90 percent would add 6 vehicles (all with very high HC/CO emitters and NOx > 2.0) to the 264 whose estimated ASM composite score would pass the cutpoint. Thus, a repair strategy that targeted only the 50 mph cruise mode would result in “successfully” repairing about 73 percent of the originally failing vehicles.

Rather than attempting to reduce the emissions on the 50 mph cruise mode by a flat percentage, the mechanic could target the typical emissions on the 50 mph cruise mode of vehicles whose ASM composite emissions pass the 1.00/8.0/2.0 cutpoint. Such a repair strategy would result in “successfully” repairing 162 (44%) of the originally failing vehicles. The distribution of those 162 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing 50 mph Cruise Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	1	2	4	2	0	42	84	24	12	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

If mechanics were able to repair those 372 vehicles so that the emissions (only HC and CO) on the idle mode were reduced by 80 or 90 percent (the model yields the same result for each) while the emissions on the other three modes remained unchanged, then only 96 of those 372 would be able to pass the 1.00/8.0/2.0 cutpoint. Thus, a repair strategy that targeted only the idle mode would result in “successfully” repairing only about one-fourth of the originally failing vehicles. The distribution of those 96 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing Idle Mode by 80 or 90%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	2	1	1	0	0	84	6	6	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Rather than attempting to reduce the emissions on the idle mode by a flat percentage, the mechanic could target the typical emissions on the idle mode of vehicles whose ASM composite emissions pass the 1.00/8.0/2.0 cutpoint. Such a repair strategy would result in “successfully” repairing only 60 (16%) of the originally failing vehicles. The distribution of those 60 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing Idle Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	1	1	2	0	0	42	6	12	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Tightening the ASM cutpoint from 1.00/8.0/2.0 to a more stringent cutpoint of 0.40/8.0/1.5 produces similar results in our model.

An ASM cutpoint of 0.40/8.0/1.5 will fail 587 vehicles in that simulated lane fleet. The distribution of those 587 vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	6	16	7	13	1	72	311	42	78	6
NOx > 2.0	0	4	3	6	0	0	24	18	36	0

As with the 1.00/8.0/2.0 cutpoint, single-mode repairs that reduced the 5015 mode emissions by 80 or 90 percent would succeed in “successfully” repairing only 108 (18 percent of the 587 failing vehicles) The distribution of those 108 vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 5015 Mode by 80 or 90%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	1	5	0	0	0	6	102	0	0	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Rather than attempting to reduce the emissions on the 5015 mode by a flat percentage, the mechanic could target the typical emissions on the 5015 mode of vehicles whose ASM composite emissions pass the 0.40/8.0/1.5 cutpoint. Such a repair strategy would result in “successfully” repairing only 54 (16%) of the originally failing vehicles. The distribution of those 54 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 5015 Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ² 2.0	1	2	0	0	0	6	48	0	0	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

If mechanics were able to repair those 587 vehicles so that the emissions on the 2525 mode were reduced by 80 percent (while the emissions on the other three modes remained unchanged), then only 138 of those 587 would be able to pass the 0.40/8.0/1.5 cutpoint. The distribution of those 138 vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 2525 Mode by 80%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ² 2.0	1	9	0	1	0	6	126	0	6	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Reducing the 2525 mode emissions by 90 percent would add 12 vehicles (6 passing HC/CO with NOx ² 2.0 and 6 marginal HC/CO emitters with NOx > 2.0) to the 138 whose estimated ASM composite score would pass the cutpoint. Thus, a repair strategy that targeted only the 2525 mode would be successful on only about 26 percent of the originally failing vehicles.

Rather than attempting to reduce the emissions on the 2525 mode by a flat percentage, the mechanic could target the typical emissions on the 2525 mode of vehicles whose ASM composite emissions pass the 0.40/8.0/1.5 cutpoint. Such a repair strategy would result in “successfully” repairing only 102 (17%) of the originally failing vehicles. The distribution of those 102 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 2525 Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ² 2.0	0	4	0	1	0	0	96	0	6	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

If mechanics were able to repair those 587 vehicles so that the emissions on the 50 mph cruise mode were reduced by 80 percent (while the emissions on the other three modes remained unchanged), then 365 of those 587 would be able to pass the 0.40/8.0/1.5 cutpoint. The distribution of those 365 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 50 mph Cruise Mode by 80%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	6	12	4	2	0	72	251	24	12	0
NOx > 2.0	0	1	0	0	0	0	6	0	0	0

Reducing the 50 mph cruise emissions by 90 percent would add 12 vehicles (all with NOx > 2.0; 6 of which with marginal HC/CO and 6 with high HC/CO) to the 365 whose estimated ASM composite score would pass the cutpoint. Thus, a repair strategy that targeted only the 50 mph cruise mode would result in "successfully" repairing about 64 percent of the originally failing vehicles.

Rather than attempting to reduce the emissions on the 50 mph cruise mode by a flat percentage, the mechanic could target the typical emissions on the 50 mph cruise mode of vehicles whose ASM composite emissions pass the 0.40/8.0/1.5 cutpoint. Such a repair strategy would result in "successfully" repairing only 275 (47%) of the originally failing vehicles. The distribution of those 275 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 50 mph Cruise Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	2	8	4	2	0	48	191	24	12	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

If mechanics were able to repair those 587 vehicles so that the emissions on the idle mode were reduced by 80 or 90 percent (the model yields the same result for each) while the emissions on the other three modes remained unchanged, then only 42 of those 587 would be able to pass the 0.40/8.0/1.5 cutpoint. Thus, a repair strategy that targeted only the idle mode would result in "successfully" repairing only about seven percent of the originally failing vehicles. The distribution of those 42 passing vehicles is given in the following table.

<u>Fleet Distribution Failing 0.40/8.0/1.5</u>
Passing after Reducing Idle Mode by 80 or 90%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	1	0	0	0	0	42	0	0	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Rather than attempting to reduce the emissions (only HC and CO) on the idle mode by a flat percentage, the mechanic could target the typical emissions on the idle mode of vehicles whose ASM composite emissions pass the 0.40/8.0/1.5 cutpoint. Such a repair strategy would have produced exactly the same result (i.e., 42 passing vehicles) as would reducing the idle emissions by a flat 80 or 90 percent.

From the preceding two examples (i.e., using cutpoints of 1.00/8.0/2.0 and 0.40/8.0/1.5), the only potentially effective “single-mode ASM repairs” are those repairs targeted at the 50 mph cruise mode (reducing emissions by 90%). However, the model predicts that those repairs would not be successful on 27 to 36 percent of the originally failing vehicles. The distributions, of those vehicles that are still failing the respective ASM cutpoint after repairs targeted on the 50 mph cruise mode (reducing emissions by 90%), are given in the following table.

<u>Still Failing 0.40/8.0/1.5</u>
After Reducing 50 mph Cruise Mode by 90%

	Still Failing Cutpoint of 1.00/8.0/2.0 Simulated Lane Fleet FTP HC/CO Emissions					Still Failing Cutpoint of 0.40/8.0/1.5 Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	High	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	6	12	54	6	0	60	18	66	6
NOx > 2.0	0	6	0	18	0	0	12	12	36	0

From the preceding table, we can see that the vehicles that the model predicts will continue to exceed the respective ASM cutpoints, even after single-mode repairs targeted at the 50 mph cruise mode, are among the highest emitters in the simulated lane fleet.

5.7 Purge Analyses

5.7.1 Introduction

In purge testing, the concern is not that too many malfunctioning vehicles will pass a test. Instead, the major concern is too many properly functioning vehicles will fail a test that attempts to replace a test with real-world driving behavior with a few steady-state modes. These steady-state modes may not provide some vehicles with the opportunity to purge. Thus, the purpose of this section was to compare the canister purge system false failure rates (errors-of-commission or Ecs) for the ASM and IM240. The data indicate that the IM240 is significantly less likely to falsely fail vehicles for purge than the ASM.

Vehicle evaporative emissions contribute significantly to the VOC inventory. Because vehicle fuel tanks and carburetors must vent to atmosphere for proper vehicle operation, carbon canisters are added to collect hydrocarbon molecules which would otherwise escape. Because the carbon canister has a finite capacity, which if exceeded, allows hydrocarbons to escape, the canister must be kept purged of stored hydrocarbon molecules. The evaporative control system includes a purge system which draws stored hydrocarbons into the engine where they are burned.

Most properly functioning canister purge systems do not purge constantly; instead, most only purge when their ECM computer algorithms call for purge. Driveability or emission problems accompany purge that initiates during unfavorable conditions, so purge algorithms are designed to take advantage of opportune conditions. The purge algorithms are known to vary widely from model to model. So, the main problem for an I/M test is to provide vehicle operation that will coincide with the conditions necessary to induce the system to activate canister purge. EPA has found that some vehicles only purge during accelerations or decelerations, which is problematic for steady state tests such as the ASM and could result in falsely failing vehicles with purge systems that are properly functioning.

Also, some vehicles have timers that don’t allow purge for several minutes after the engine is started or a specified operating temperature is reached, so all else being equal, the longer the test duration, the lower the probability of purge false failures. This also makes the test order important, since the test that was performed second is more likely to achieve purge than the initial test. This is one reason the test procedure in our study in Mesa required the test order to be reversed each time another car was tested and why the engine was restarted just before each test.

The IM240 purge flow was summed over the full IM240. The ASM purge flow was measured and summed over the full four modes of the ASM including transient segments of the ASM cycle, in contrast to the ASM exhaust emissions, which were only measured during the four ASM steady-state modes. Because the flow measuring equipment is the same for both transient and steady-state tests, it was practical to measure purge flow on the ASM during the three accelerations and the single deceleration needed to complete the four ASM modes.

5.7.2 The Database

The database for the lane purge analysis was restricted to vehicles that met all of the following criteria:

- as-received purge data were available for both the IM240 and the ASM,
- the test order was known,
- and the data passed the purge QC criteria (see Appendix C).

The resulting database consisted of 1170 vehicles. Of these, 577 received the IM240 first and 593 received the ASM test first. The comparisons made for this analysis included failure rate comparisons, and comparisons of vehicles for which the ASM and IM240 purge status did not agree, or "false failures". In addition, these comparisons were made for data stratified by test order. The standard used for these comparisons was 1.0 liter/test.

5.7.3 The Results

The results of the failure rate comparisons are as follows:

- Overall purge failure rates:
  - The IM240 failed 7.43% (87 vehicles).
  - The ASM failed 11.45% (134 vehicles).

- Initial test failure rates:
  - The IM240.1st failed 6.93% (40 vehicles).
  - The ASM.1st failed 11.13% (66 vehicles).

- Second test failure rates:
  - The IM240.2nd failed 7.92% (47 vehicles).
  - The ASM.2nd failed 11.79% (68 vehicles).

These higher failure rates for the ASM raise the question of whether the ASM correctly identified non-purging vehicles that the IM240 missed, or whether the ASM incorrectly failed vehicles. Passing the IM240 purge test requires either that purge actually occurs or that the measurement system falsely indicate that purge is occurring. Since the ASM and IM240 were run with the same measurement system, and results were reported electronically without human intervention, it is not conceivable that a measurement error made some cars pass the IM240 and fail the ASM. Consequently, the ASM-fail/IM240-pass cars must be considered improper fails by the ASM, and vice versa, with a possibility that test order was a contributing factor in specific cases despite the engine restart for both tests. However, since the sample has essentially an equal number of each test order, test order should not be a relevant factor overall.

The next set of statistics implies that both the ASM and the IM240 falsely fail vehicles, but the ASM falsely fails more vehicles.

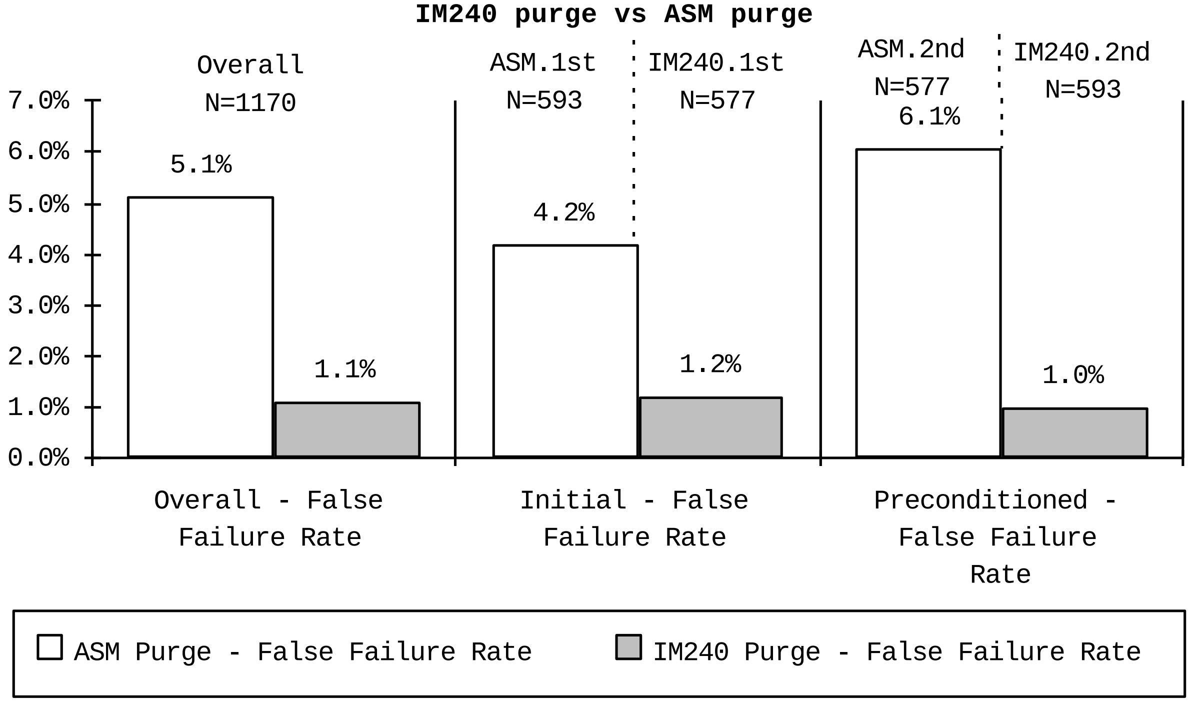
- Overall false failure rates (fails one test but not the other):
  - 1.1% or 13 vehicles failed the IM240 but passed the ASM.
  - 5.13% or 60 vehicles failed the ASM but passed the IM240.

- False failures on initial test:
  - The IM240.1st falsely failed 1.21% (7 vehicles).
  - The ASM.1st falsely failed 4.22% (25 vehicles).

- False failures on second test:
  - The IM240.2nd falsely failed 1.01% (6 vehicles).
  - The ASM.2nd falsely failed 6.07% (35 vehicles).

Figure 5.7.1 graphically illustrates the comparison of false failure rates.

Figure 5.7.1
Comparison of False Failure Rates for IM240 purge vs ASM purge



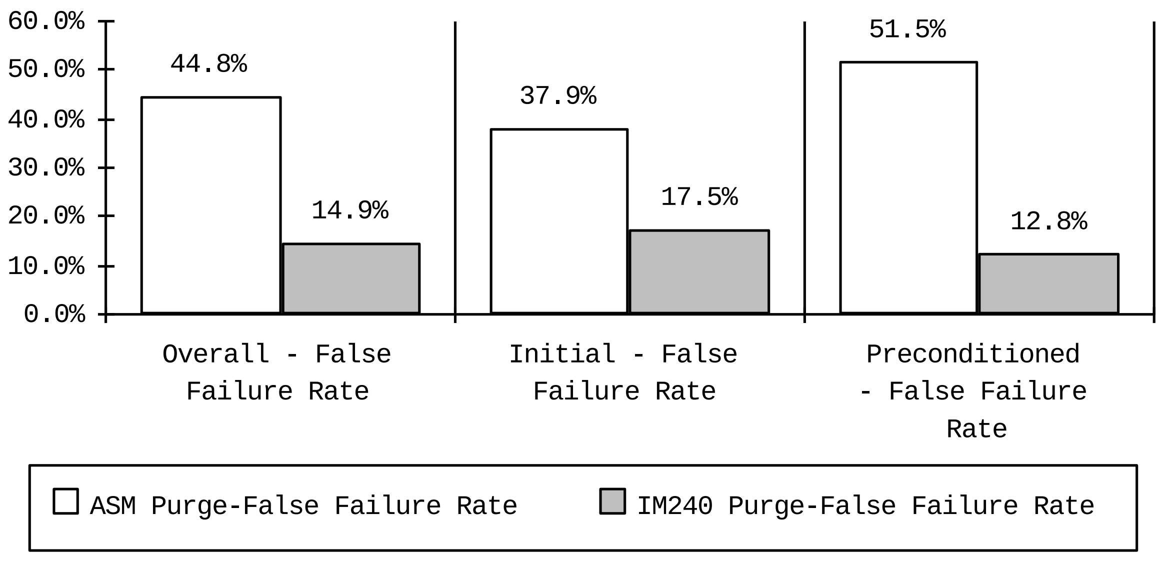
The most relevant comparison is the initial tests (ASM.1st & IM240.1st) because they are more representative of the conditions and vehicle preconditioning expected in official I/M programs than the preconditioned tests. The purge results for the initial tests were similar to the overall results; the ASM.1st's false failure rate was 3 percentage points higher than for the IM240.1st.

With a 3 to 4% false failure rate, the ASM purge test could cause severe problems to I/M programs in the form of frustrated consumers and skeptical mechanics.

As discussed in the introduction, test order was expected to be important because the test that was performed second would be more likely to achieve purge than the test that was performed first. Contrary to expectations, however, the ASM.2nd exhibited a 0.63% increase in failure rate and a 1.85% increase in false failures when compared to the ASM.1st. The the IM240.2nd also produced a higher failure rate (+1.0%) than the IM240.1st, but the IM240.2nd's false failures decreased 0.2% compared to the IM240.1st.

In addition, the false failure rate for the IM240.2nd is markedly better than for the ASM.2nd when viewed as a percentage of failures. Figure 5.7.2 shows that the false failure rate dropped from 17.5% of the failing IM240.1st vehicles to 12.8% of the failing IM240.2nd vehicles. In contrast, the false failure rate increased to 51.5% of the ASM.2nd failing vehicles from 37.9% of the ASM.1st failing vehicles. So although the false failure rate for both tests is expected to decrease further if the engine restart is avoided before performing the second-chance test, these data suggest that retesting is more effective in reducing IM240 false failures than ASM false failures.

Figure 5.7.2
False Failure Rates as a Percentage of Failures
for IM240 purge vs ASM purge



Overall, 74 vehicles failed both the ASM and IM240. The ASM falsely failed 60 additional vehicles while the IM240 falsely failed only 13 additional vehicles. As shown in Figure 5.7.2, 44.8% of the 134 vehicles failing the ASM purge were false failures compared to 14.9% of the 87 vehicles failing the IM240 purge. In addition, 37.9% (25 of 66) of the ASM.1st falsely failed compared to 17.5% (7 of 40) IM240.1st false failures. Of the 68 vehicles that failed the ASM.2nd 35 had purged on the IM240, so 51.5% of the ASM.2nd failures were false failures, whereas only 6 of the 47 vehicles that failed the IM240.2nd had purged on the preceding ASM, so 12.8% of the IM240.2nd failures were false failures.

These results indicate that the ASM error-of-commission rate will be intolerably high with one third to one half of failing vehicles being false failures. I/M programs could implement a second chance test immediately following the first test without shutting off the engine to reduce false failures. However, it is speculative whether this will significantly reduce the ASM false failure rate. Also, second-chance testing adds cost. Since the false failure rate increases from the ASM.1st to the ASM.2nd and decreases for the IM24.2nd compared to the IM240.1st (See Figure 5.7.2), the data indicates that second-chance testing may not be as effective for the ASM as for the IM240.

Second-chance testing costs will be lower for the IM240 because it fails fewer cars initially, thus, requiring fewer retests and some vehicles just do not purge during steady-state operation. For these vehicles, an alternate cycle such as the IM240 would be required. Dynamometer costs would then increase because inertia simulation is needed, but the more expensive IM240 exhaust measurement systems would not be needed.

In summary, the comparison of ASM purge and IM240 purge shows that the IM240 is superior in correctly identifying vehicles with malfunctioning purge systems. With false failure rates of 4 to 6% for the ASM (3 to 6 times higher than IM240 false failure rates), an additional second-chance test will be required. And since some vehicles simply do not purge on the ASM steady-state modes, even with purge measured during the accelerations between modes, an alternate cycle such as the IM240 may be required for retests. In conclusion, the ASM purge test is substantially less effective than the IM240 purge test.

5.8 IM240 Improvements and the Four-Mode IM240

The purpose of this section is to convey that refinements are possible which would make the IM240's performance a "moving-target," and to further reiterate why one sample should be used to develop the ASM-mode weighting factors and an independent sample used to evaluate the ASM's effectiveness.

EPA's recommended IM240 cutpoints of 0.80/15.0/2.0 + 0.50/12.0 represent a compromise between failing high emitting vehicles and not failing clean vehicles. As cutpoints are tightened, the IDRs generally increase at the expense of increasing the possibility of errors-of-commission. Increasing the power of the test (i.e., the ability to distinguish between malfunctioning and properly functioning vehicles) serves the public good, in that the high emitters not identified by the test are not repaired, so the cost of testing such vehicles is not rewarded by air quality improvements that accrue from identifying and repairing such vehicles. More tangible is that vehicle owner satisfaction and acceptance of I/M programs increase with lower errors-of-commission.

EPA is not content for all time with the absolute performance of the IM240 as now defined. Although in a relative sense, its performance is superior to any of the alternative I/M tests, it can be improved. Consider for example the IM240's 15 g/mi CO cutpoint. This is more than four times the FTP CO standard, and unlike the FTP which includes a cold start [9], the IM240 is to be performed on fully warmed up vehicles. So the errors of omission (vehicles which pass, but should not) are higher than if a more stringent CO standard were used. EPA testing has shown that tighter cutpoints will identify more high emitters, but also fail some properly functioning vehicles. Although the IM240 is considerably better than any alternative I/M test, in this regard, there is no question that its performance can be improved. The IM240's performance can be improved in two areas:

- Reduce the test-to-test variability so that cutpoints can be tightened without falsely failing clean vehicles.

- Use statistical techniques to improve the IM240 's correlation with the FTP.

Such improvements will serve the public interest by increasing the air quality yield per test-dollar, so alternative tests should be evaluated against the state-of-the-art of IM240 testing rather than the IM240 performance, as it existed, when the I/M Rule was published. Proponents of alternative I/M tests may point out that if the IM240's performance, as it stood in November 1992, was good enough to meet the performance standard, then this performance standard should be the standard for alternative tests. While such a policy may indeed "level-the-playing-field" for alternative tests and is in fact what is allowed by EPA's I/M Rule, it is difficult to argue that this approach promotes the general welfare and should guide state and local decision-makers concerned as much about clean air as about meeting minimum requirements.

5.8.1 Reduce Test-to-Test Variability

Test-to-test variability is the primary reason why the IM240's cutpoints are so much less stringent than the FTPs. The FTP controls a number of variables that are widely known to affect a given vehicle's emissions. Some variables that are tightly controlled for FTPs were either more loosely controlled or not controlled in EPA's IM240 lane tests. These include, among others:

---

[9] CO (and HC) emissions are considerably higher during warmup than during fully warmed-up operation.

- ambient temperatu re in the test cell
- humidity in the test cell
- engine temperature (FTP indirectly controls with preconditioning and ambient conditions)
- catalyst temperature (FTP indirectly controls with preconditioning and ambient conditions)
- vehicle operation prior to the emissions test (can affect emission control system timers for purge, air switching, etc., and other variables affecting emissions)
- evaporative canister loading (FTP indirectly controls with ambient conditions and vehicle operation during the 12 hours preceding the FTP emissions test)
- tire pressure
- speed excursions from the nominal speed (±2 mph on FTP vs. driver discretion for EPA’s pilot IM240 testing to date)
- exhaust system backpressure (NOx can be adversely affected by a constant volume sampler if quality control is not adequate)
- fuel composition

EPA has already made improvements that I/M programs will be required to implement, but were not implemented during EPA’s testing. For example, FTPs are voided if speed excursions from the nominal speed exceed ±2 mph. In contrast, much of EPA’s data are from vehicles with speed excursions that exceed ±2 mph. In a committee that included I/M contractors, state I/M program officials, IM240 equipment manufacturers, and automobile manufacturers, a consensus was reached on requiring this tighter speed tolerance along with additional tighter controls that will reduce test-to-test variability [10].

There are also variables that can not be controlled, such as ambient temperature and canister loading, but can be compensated for to better distinguish between malfunctioning and properly functioning vehicles. Given enough data, computer algorithms can be developed that consider the more important variables and apply adjustment factors to the official IM240 test results.

Simplistic approaches such as setting tire pressure or providing second-chance tests for vehicles that are within 1.5 times the cutpoints seem costly to implement because additional I/M lanes and personnel are needed, but are judged to be cost effective since vehicles that should not fail but do, must be retested after “repairs” anyway.

More sophisticated algorithms utilizing sensors to measure variables like ambient temperature and catalyst temperature allow relationships to be developed and used to compute scores. These are more efficient because they can increase the power of the test without requiring additional I/M lanes and personnel. Developing these techniques will require

[10] Draft High-Tech Test Procedures, Quality Control Requirements, and Equipment Specifications, April 5, 1993.

substantial data. When the IM240 is implemented, much data will become available to allow development of such algorithms.

5.8.2 Statistical Techniques to Improve the IM240's Correlation With the FTP

Presently, the IM240 score constitutes the sum of the mass emissions divided by the distance accumulated. Because almost every second of operation is taken from various segments of the FTP, the two tests correlate better than any existing alternative I/M test. But their correlation can be improved using multiple regression. For example, the uncontrolled variables that attend IM240 tests probably make it appropriate to de-emphasize the initial operation of the IM240 in computing the score and emphasizing the later operation. The later operation is somewhat preconditioned by the initial operation. Also, the IM240 has a higher average speed than the FTP, so de-emphasizing the high speed portions should produce a better correlation with the FTP.

The data itself can be used to determine the more appropriate weighting through the use of regression techniques. For example, EPA divided the IM240 into four modes as follows:

Mode 1: 0-60 seconds
Mode 2: 61-119 seconds
Mode 3: 120-174 seconds
Mode 4: 175-239 seconds

As for the ASM, coefficients are developed by performing a multiple regression wherein the results from four modes are the independent variables and the FTP results is the dependent variable, which allows the data to determine the appropriate mode weighting.

EPA tried this using the only substantial database with the information needed (FTPs with IM240 4-mode results or second-by-second results), which happens to be the vehicles on which this report focuses. So the coefficients had to be developed on the same set of data to which they were applied. EPA condemns this practice, as discussed in Section 5.5, but having no alternative, the results are presented only to provide an indication of how the IM240's performance is enhanced through this approach.

Unfortunately, the legitimate performance increase gained by using multiple regression to determine appropriate mode weighting can not be isolated from the inappropriate application of these coefficients to the same vehicles from which they were developed. So the performance presented in Table 5.8.2 gives an overly optimistic view, but also reiterates that ASM-advocates who do not accept EPA's judgement that it is inappropriate to apply coefficients to the vehicles from which they were developed, should then compare the ASM performance with inter-linked coefficients to the IM240 also utilizing inter-linked coefficients.

The multiple regression was performed on the first 91 vehicles in the database only (this analysis was not repeated when additional data became available). The results are presented in Tables 5.8.1 and 5.8.2. The negative coefficients in Table 5.8.1 indicate that insufficient data is available for developing logical coefficients, which will compensate, to some degree for the inter-linked performance listed in Table 5.8.2.

Table 5.8.1
Coefficients Developed from
Multiple Regression of 4-Mode IM240 vs. FTP

Mode	HC	CO	NOx
Constant	0.03	-0.28	-0.02
1	-0.30	-0.18	-0.07
2	1.16	1.70	0.37
3	0.26	-0.01	0.02
4	0.09	-0.08	0.56
R^2	90.3%	86.0%	69.6%

Table 5.8.2 illustrates how the 4-Mode test improves the tradeoff between IDRs and Ec rates at equivalent failure rates.

Table 5.8.2
4-Mode IM240 Performance Versus Normal IM240

Fail Rate	**IDRs**						**Ecs**	
	HC		**CO**		**NOx**			
	4-Mode	Regular	4-Mode	Regular	4-Mode	Regular	4-Mode	Regular
12%	88%	88%	65%	63%	72%	75%	0.0%	0.4%
13%	90%	90%	66%	65%	75%	76%	0.0%	0.4%
14%	91%	91%	66%	66%	78%	78%	0.4%	0.7%
15%	92%	91%	66%	66%	75%	78%	0.4%	0.7%
19%	91%	93%	72%	68%	83%	82%	0.4%	1.4%
20%	94%	93%	72%	69%	86%	82%	0.4%	1.8%
23%	95%	93%	73%	69%	88%	83%	0.7%	3.9%

Notice the performance increase in that the IDRs increase and errors-of-commission decrease.

In conclusion, developers of alternative I/M tests should not consider the performance of the IM240 to be fixed. While better than any existing I/M tests, IM240 improvements are possible and desirable. EPA’s mission to improve air quality and enhance the public welfare necessitates evaluating alternative tests, not against the performance of the IM240 as it was in November 1992 when the I/M Rule was published, but instead, against the state-of-the-art.

6. Test Programs by Other Organizations

6.1 Colorado Test Program

The Colorado Department of Health (CDH) completed an evaluation [11] comparing the FTP and the IM240 to the following eight I/M test modes, in the order the modes were performed:

- 35 mph road load
- 50 mph road load
- ASM 2545
- ASM 2525
- ASM 5015
- Idle test
- 2500 rpm

Their conclusions included the following:

> "The loaded mode [IM240] tests (both [93] second and 240 second] identify significantly more of the excessively emitting vehicles and more of the excess emissions than do any of the steady-state tests. They also have fewer errors of commission and less sensitivity to differences between FTP and short test emission levels. With no other consideration, either the 95 second or the 240 second version of the [IM240] would be the clear choice for the most accurate and effective identification of excessively emitting vehicles."

6.2 California Test Program

EPA has received a preliminary analysis [12] from the California Air Resources Board (CARB) comparing the ASM5015 and the ASM2525 to the IM240. The CARB analysis looks favorably on the ASM modes and concludes that the ASM tests are as effective as the IM240. However, there are significant concerns with CARB's data. These concerns include the following:

- The CARB database is not representative of the newer fleet.
- CARB's testing is not representative of actual I/M testing.
- All of CARB's tests were preconditioned.
- CARB's ASM equations, when applied to EPA's data, demonstrate poor performance.

[11] Ragazzi, et al.

[12] Draft Memorandum from Jeff Long, Manager, Analysis Section to Mark Carlock, Chief, Motor Vehicle Analysis Section, "Comparison of Excess Emissions Identified by IM240, ASM5015 and ASM2525 Tests," California Air Resources Board, not dated, received April 15, 1993.

EPA is preparing a separate document that will consider CARB’s ASM test program in more detail.

7. Test Costs Comparison

Supporters of the ASM have frequently suggested that it would be a more cost-effective test than the IM240, given that the equipment cost is significantly lower. As Table 5.12.1 shows, the equipment package for the ASM series, with purge and pressure testing, does have a lower total cost than the IM240, purge, and pressure equipment package.

Table 7.1
Equipment Costs for the ASM Series and IM240

IM240		ASM	
Equipment	Cost	Equipment	Cost
Pressure Rig	$600	Pressure Rig	$600
Purge Meter	$500	Purge Meter	$500
VDA	$1,000	VDA	$1,000
Dynamometer	$25,000	Dynamometer	$20,000
CVS & Analyzers	$79,000[13]	BAR90 & NOx Bench	$19,000
Total	$106,100		$41,100

These figures reflect the most recent cost information that EPA has received from industry. EPA has published previous estimates of the per vehicle costs of ASM and IM240 testing in "I/M Costs, Benefits, and Impacts," in November, 1992. EPA found, and independent analyses confirmed, that equipment costs, when spread over the useful life of the equipment, constitute a relatively small portion of the per vehicle cost of an I/M test; labor and overhead costs are considerably higher. In analyzing the current average per vehicle inspection cost in a centralized program of $8.50, EPA estimated that equipment accounted for 21¢, labor for 96¢, 82¢ went to defray construction costs, the state oversight fee averaged $1.25, and the remaining $5.26 went to cover various overhead costs (for a full discussion of EPA's cost estimation assumptions and methodology the reader is referred to Sections 5.2 and 5.3 of "I/M Costs, Benefits, and Impacts," contained in Appendix H). Current testing stations have an average peak capacity of 25 vehicles per hour and enough stations are constructed to avoid long lines on peak demand days. Given the typical pattern of owners' choices about when to come for inspections, this results in an average actual throughput of 12.5 vehicles per hour which translates into 39,000 vehicles per year per lane, and costs are spread over a multi-year period, five years in most cases.

Throughput is the most critical variable in estimating costs since it determines the size of the inspection station network needed for a given area and the number of vehicles

---

[13] Letter from Kenneth W. Thomas, Marketing Manager, I/M Systems, Horiba Instruments Incorporated, to Bill Pidgeon, U.S. Environmental Protection Agency, April 7, 1973 and Quotation from Scott P. Corrunker, Sales Engineer, Combined Fluid Products Company to Dan Sampson, U.S. Environmental Protection Agency, January 27, 1993. These are attached as Appendices J and K.

over which costs for each lane are spread. Inspection lanes usually have more than one position, with different parts of the inspection performed at each one. Hence, throughput is governed not by the time required to perform the total test sequence, but by the time required at the longest position. Whether the test sequence consists of the IM240 with purge and pressure testing or the ASM with purge and pressure testing, the longest part of the sequence is the tailpipe emissions test.

The combined IM240 and purge test takes approximately three minutes (using fast-pass and fast-fail) to perform on the average. Allowing an additional minute to maneuver the vehicle onto the dynamometer and otherwise prepare the vehicle for testing the total time at the longest position is estimated to be four minutes. This translates into a peak lane capacity of 15 vehicles per hour and an average actual throughput of 7.5 vehicles per hour. The ASM consists of four modes lasting 40 seconds each with a few seconds in between to change speed. This works out to approximately three minutes per test. Allowing, again, an additional minute to maneuver the vehicle onto the dynamometer and otherwise prepare it for testing, the total test time is about four minutes, hence, the throughput rates for the ASM is the same as for the IM240. Average throughput for both tests is 7.5 vehicles per hour. Assuming that stations operate 60 hours per week, 52 weeks per year, and costs are spread over a five year period, then equipment costs are spread over a total of 117,000 vehicles.

The optimum lane configuration for both tests is a three position lane staffed by three inspectors. Consequently, as shown in “I/M Costs, Benefits, and Impacts,” staff, infrastructure and overhead costs are essentially the same for both tests. The only difference is in the cost of equipment. Table 5.12.2 shows the estimated per vehicle costs for performing the ASM and the IM240. The costs are derived using the same methodology and assumptions as in Appendix H. Overhead costs for IM240 and ASM tests are estimated by factoring the overhead for current centralized programs by the change in throughput. Equipment, and construction costs are obtained by dividing those costs over the total vehicle traffic in a five year period. Staff costs are obtained by dividing inspectors' hourly wages ($6.00) by the average number of vehicles inspected in a hour. State oversight costs are estimated at $1.75 per vehicle but could vary depending upon the intensity of the state oversight program; they would not vary between the two test types.

Despite the difference between the costs of the equipment packages required for the two tests, the total cost per vehicle, factoring in all necessary costs involved in a testing program, differs very little between the two tests. In a high volume test program the per vehicle cost difference is estimated at 74¢; the per vehicle cost for the ASM is about 5 percent less than for the IM240.

Table 7.2
Cost Components and Cost per Vehicle for the ASM and IM240

IM240		ASM
$2.40	Inspection Staff	$2.40
$1.75	State Oversight	$1.75
$1.39	Test Equipment	$0.65
$1.71	Building Modification/Construction	$1.71
$9.12	Other Overhead	$9.12
$16.37	Total Cost Per Test	$15.63

8. Evaluation of the Adequacy of the ASM for Enhanced I/M Programs

8.1 Introduction

The preceding chapters show that the four-mode ASM test is not equivalent to the IM240 on a per-car basis. Even if ASM cutpoints are selected so that the same number of cars are failed, they will represent a smaller portion of the fleet's excess emissions, and the cars will not be repaired as effectively as if the IM240 were used for reinspection after repair. However, to some extent this loss of emission reduction can be compensated for by improving other I/M program features to make them more stringent than would otherwise be required to meet the emission reduction performance standard in EPA's rule for enhanced I/M programs. Among these other features are the inspection of heavy-duty gasoline-fueled vehicles, the use of the ASM test for all 1981 and newer vehicles rather than just the 1986 and newer vehicles which are assumed to be tested with the IM240 in the model I/M program, a higher failure rate for pre-1981 vehicles, purge testing for more model years than in the model program, and more comprehensive tampering inspections.

Whether these im provements are enough to offset the loss of benefit from the ASM is the decisive question that determines whether areas subject to the enhanced I/M program requirement can rely on ASM testing instead of IM240 testing. Also of interest is whether it is possible to use the ASM and still operate a biennial program. To answer these questions, EPA examined annual and biennial scenarios in which the ASM cutpoints were made as stringent as EPA believes is consistent with good engineering practice and the possible offsetting program improvements were made as large as EPA considers reasonably possible. If this hypothetical best-possible ASM program cannot satisfy the enhanced I/M performance standard, then no ASM program can.

Regarding best-possible ASM cutpoints, EPA has assumed that the failure rate associated with the most stringent IM240 cutpoints for which EPA has provided emission reduction credits is the limit of good engineering practice in an I/M program. These IM240 HC/CO/NOx cutpoints are 0.6/10.0/1.5, compared to the 0.8/20.0/2.0 used in the model enhanced I/M program. The ASM cutpoints that matched this failure rate in the full Mesa lane sample were 0.40/8.0/1.8. These ASM cutpoints can be expected to produce a higher error of commission rate than the 0.6/20.0/2.0 IM240 cutpoints, but in the interest of exploring the limits of ASM testing, EPA assumed that this did not make them unacceptable. EPA calculated MOBILE5a I/M credits for these ASM cutpoints, using the same basic approach as originally used for the IM240 credits. We then used MOBILE5a with these credits and appropriate assumptions for the offsetting program improvements to determine the overall benefit of a best-possible hypothetical ASM program. Further description of this process follows.

8.2 MOBILE5a Analysis

The I/M credits for the ASM test procedure were determined using the identification rate from the Arizona test sample. The laboratory sample was weighted as described in Section

5.2.5.8 to reverse the effect of the recruitment bias. The fraction of total emissions identified by the ASM test with best-possible cutpoints and the IM240 test with its standard cutpoints were determined for that sample [*]. Using the IM240 results for the Arizona sample, the ASM identification rates were converted to a fraction of the IM240 results. These fractions were then used in the I/M credit model to adjust the IM240 identification rates used in MOBILE 5 to represent the effect of the ASM test.

For repair effects, based on current information, EPA can only give the ASM test the same repair effect as the 2500/Idle test procedure for HC and CO. For NOx, the ASM test was temporarily assumed to have the same repair effect as the IM240 test procedure using a 2.0 NOx cutpoint, the nearest available to the 1.8 ASM cutpoint. At this time, we made this temporary assumption for NOx so that the ASM program can be analyzed for all three pollutants even though the repair effectiveness problems found for HC and CO appear to be similar for NOx. Unlike HC and CO, there is no set of alternative repair effectiveness numbers available that could be used since steady-state tests have never been used for NOx control in the past.

Using the ASM credit set described above, we proceeded to perform MOBILE5a runs for four separate I/M program scenarios: a no-I/M run, an enhanced I/M performance standard run, and two ASM runs, one assuming an annual testing program, and the other, a biennial program. All four scenarios assume national default inputs for the local area parameter record - including vehicle registration mix, ambient temperature, average VMT, fuel RVP, average speed, etc. - and cover evaluation years ranging from 2000 to 2011. Depending on the ozone classification, states must show in the 1993 SIP that the I/M program selected meets the performance standard in these evaluation years.

Both ASM runs were identical, with the exception of the above-noted difference in test frequency. The other program parameters assumed for the ASM runs include a program start year of 1983, a test-only network, and ASM testing of model year 1981 and later light-duty vehicles and light-duty trucks. The ASM runs also assumed evaporative system purge and pressure testing, and visual inspection of the catalyst, inlet restrictor, gas cap, air pump, EGR, tailpipe lead test, and PCV system on all 1971 and later model year vehicles. Full purge benefits were given for ASM testing, since ASM purge testing will fail virtually all cars that would fail the IM240 test. A pre-1981 stringency of 40% was assumed, along with a 3% waiver rate and a 96% program compliance rate.

Once these MOBILE5a runs were complete, we compared the results for the enhanced I/M performance standard run and the ASM runs with the no I/M case to determine what percent reduction was required to meet the performance standard and what reductions could be

---

[*] For convenience in calculations, MOBILE5a I/M credits for a particular test and cutpoints are developed starting with the total emissions identification rate, rather than the excess emission identification rate used in earlier sections, to more readily display the relative effectiveness of tests. The difference does not affect the final result.

expected from the annual and biennial ASM programs modeled. The results are shown in Table 8.1.

Table 8.1
MOBILE5a Emission Factors and Reductions from ASM Testing

	VOC			CO			NOx*		
	g/m	Redux	OK?	g/m	Redux	OK?	g/m	Redux	OK?
2000 No I/M	2.88						2.27		
Enhanced Performance Standard	1.96	32.0%					1.97	13.5%	
Maximum Annual ASM	2.00	30.5%	NO				1.93	15.0%	YES
Maximum Biennial ASM	2.07	27.9%	NO				1.96	13.9%	YES
2001 No I/M				22.23					
Enhanced Performance Standard				13.98	37.1%				
Maximum Annual ASM				15.08	32.1%	NO			
Maximum Biennial ASM				15.79	29.0%	NO			
2003 No I/M	2.66						2.10		
Enhanced Performance Standard	1.68	36.6%					1.77	15.8%	
Maximum Annual ASM	1.81	31.8%	NO				1.76	16.3%	YES
Maximum Biennial ASM	1.87	29.4%	NO				1.78	15.0%	NO
2006 No I/M	2.52						2.02		
Enhanced Performance Standard	1.53	39.2%					1.67	17.2%	
Maximum Annual ASM	1.71	32.3%	NO				1.67	17.0%	NO
Maximum Biennial ASM	1.76	30.1%	NO				1.70	15.7%	NO
2008 No I/M	2.47						1.97		
Enhanced Performance Standard	1.47	40.3%					1.62	17.8%	
Maximum Annual ASM	1.66	32.6%	NO				1.63	17.4%	NO
Maximum Biennial ASM	1.72	30.4%	NO				1.66	16.1%	NO
2011 No I/M	2.39						1.94		
Enhanced Performance Standard	1.39	41.8%					1.58	18.8%	
Maximum Annual ASM	1.60	33.1%	NO				1.60	17.6%	NO
Maximum Biennial ASM	1.65	30.9%	NO				1.62	16.3%	NO

* With temporary assumption for NOx repair benefits, as described in text.

By comparing the ASM results to the performance standard, we conclude that neither the maximum annual nor the maximum biennial ASM program would meet the performance standard for

HC or CO for any of the milestone years. For NOx, the biennial ASM program with the temporary assumption for NOx repair benefits meets the performance standard in 2000, but misses it for each successive milestone, while the annual ASM program meets the performance standard through the 2003 milestone.

These NOx results include a caveat, however. The degree to which the ASM NOx benefit in the table exceeds the performance standard is quite small. If the percent NOx repair benefit for ASM testing is anything less than 90% (i.e., 13.5%/15.0%) as good as for IM240 testing, the Maximum Annual ASM program will not meet the NOx performance standard in 2000. The corresponding “actual values” for the Maximum Biennial ASM program in 2000 and the Maximum Annual ASM program in 2003 are 98% (13.5%/13.8%) and 97% (15.8%/16.2%), respectively. While EPA for the present reserves judgment on exactly how much NOx repair benefit is lost with ASM testing, (while we consider a test program to further explore this question) it is clear from Section 5.3 that the loss is certainly at least 10%. Thus, ASM testing cannot meet the performance standard for any pollutant for any milestone date, and therefore is not an acceptable test in any enhanced I/M program.

9. Appendices Table of Contents